604-CD-004-001

## EOSDIS Core System Project

# ECS Operations Concept for the ECS Project: Part 2, FOS

October 1995

Hughes Information Technology Corporation
Upper Marlboro, Maryland

# ECS Operations Concept for the ECS Project: Part 2, FOS

**October 1995**

Prepared Under Contract NAS5-60000
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**SUBMITTED BY**

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|---|---|
| Cal E. Moore /s/ | 9/29/95 |
| Cal Moore, FOS CCB Chairman<br>EOSDIS Core System Project | Date |

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# Preface

This document is a formal contract deliverable intended to be a final submittal with an approval code 1. It requires Government review and approval prior to acceptance and use. This document is under ECS contractor configuration control. Once this document is approved, Contractor approved changes are handled in accordance with Class I and Class II change control requirements described in the EOS Configuration Management Plan, and changes to this document shall be made by document change notice (DCN) or by complete revision.

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# Change Information Page

| List of Effective Pages | |
|---|---|
| **Page Number** | **Issue** |
| Title | Submitted as Final |
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# Contents

## Preface

## 1. Introduction



## 2. Related Documentation



## 3. Flight Operations Concepts

## Abbreviations and Acronyms

# 1. Introduction

## 1.1 Identification

This document is Part 2, FOS submittal of the ECS Operations Concept Document (OCD). It is submitted as required by Contract Data Requirements List (CDRL) item number 112 and Data Item Description (DID) 604/OP1 for the NASA Contract NAS5-60000.

## 1.2 Scope

The focus of this document describes a concept of operations for the ECS FOS within the context of EOSDIS, the Earth Observing System (EOS), and the Mission to Planet Earth (MTPE). Much of the information contained in this document was part of an earlier submittal of the Operations Concept for the ECS Project in August 1994. Since then, the CDRL requirement has been revised to provide an overall release-neutral concept document (604, Part 1) and release-specific documents (604, Part 2).

## 1.3 Purpose and Objectives

This document will provide guidance to system engineers during the system design phase to ensure that the system architecture and design will accommodate the operational concepts and the system users'/providers needs. It will provide a basos for detailed scenarios in other FOS documents such as test and acceptance plans and procedures, as well as the Operations Scenarios Document (605/OP2). It will provide guidance for the establishment of staffing plans. It will define operational roles. It will help to define the performance of the individual system elements and the performance between those functional elements.

Throughout the mission life, this OCD will serve as an information source describing the FOS mission, and FOS capabilities and oeprations.

## 1.4 Status and Schedule

This document is intended as a final submittal as required to support the CDR-FOS milestone. Once approved, updates will be made via Document Change Notice (DCN) or total revision if appropriate.

## 1.5 Document Organization

The contents of this document are organized in the following six sections and one appendix:

| | |
|---|---|
| Section 1 | Introduction - Introduces the ECS OCD scope, purpose, objectives, status, schedule, and document organization. |

| | |
|---|---|
| Section 2 | Related Documentation - Provides a bibliography of reference documents for the ECS OCD organized by parent, reference, and information subsections. |
| Section 3 | Flight Operations - Describes the EOS flight operations center, its interfaces and ops staff. Also described are the flight ops activities - - scheduling, command management, real time telemetry and commanding, and spacecraft and instrument health and performance monitoring. |

# 2. Related Documentation

## 2.1 Parent Documents

The following documents are the parents from which this document's scope and content are derived:

| | |
|---|---|
| 423-41-01 | Goddard Space Flight Center, EOSDIS Core System (ECS) Statement of Work |
| 423-41-02 | Goddard Space Flight Center, Functional and Performance Requirements Specification for the Earth Observing System Data and Information System (EOSDIS) Core System (ECS) |

## 2.2 Applicable Documents

The following documents are referenced within this FOS Operations Concept, or are directly applicable, or contain policies or other directive matters that are binding upon the content of this volume.

| | |
|---|---|
| 604-CD-001-004 | Operations Concept for the ECS Project:  Part 1-- ECS Overview |
| 605-CD-003-001 | Flight Operations Segement (FOS) Operations Scenarios Document |
| FB9402V2 | ECS Science Requirements Summary, White Paper, Working Paper |
| none | Goddard Space Flight Center, Draft EOSDIS Science Operations Concept |
| none | Goddard Space Flight Center, Earth Observing System Mission Operations Concept Document |
| CSC/TR-91/6005 | Goddard Space Flight Center, EOSDIS Flight Operations Segment Operations Concept, 3/91 |

## 2.3 Information Documents

The following documents, although not directly applicable, amplify or clarify the information presented in this document:

| | |
|---|---|
| 205-CD-001-002 | Science User's Guide and Operations Procedure Handbook [for the ECS Project], Parts 1-3, |
| NASA  NP-202 | EOS Reference Handbook |

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# 3. Flight Operations Concepts

The EOS Operations Center (EOC) performs mission planning, command and control of the U.S. EOS spacecraft and the U.S. EOS instruments, and coordinates mission operations for other non-U.S. EOS instruments on-board the U.S. spacecraft. The EOC operations support the EOS mission life cycle, which includes pre-launch, launch, and on-orbit operations that occur in parallel with operator simulations training as well as interface tests, system tests, and end-to-end tests; supports concurrent operations with maintenance, system upgrades, and sustaining engineering activities; and supports command, control, and analysis of multiple spacecraft and their instruments simultaneously.

The EOC is located at the Goddard Space Flight Center in Greenbelt, Maryland, and is operated by the Flight Operations Team (FOT). The Flight Operations Team is responsible for maintaining spacecraft and instrument health and safety, monitoring spacecraft performance, performing spacecraft engineering analysis, performing high-level monitoring of the mission performance of the instruments, and providing periodic reports to document the operations of the spacecraft and instruments.

U.S. EOS instrument operations are distributed through the use of Instrument Support Terminal (IST) toolkits, which are deployed at instrument Principal Investigator/Team Leader (PI/TL) facilities. IST toolkits enable PI/TLs to remotely participate in the planning, scheduling, monitoring, and analysis of their instruments in conjunction with the FOT at the EOC.

Currently, all identified U.S. EOS instruments are managed at the EOC with access provided to the PI/TL via the IST. If, in the future, a complex instrument requiring a dedicated facility for control and monitor functions is identified, an Instrument Control Center (ICC) may be established.

### Flight Operations Activities

Eight services have been defined to support flight operations. These services are Planning and Scheduling, Command Management, Command, Telemetry, Resource Management, Analysis, Data Management, and User Interface. Individually these services perform specific, unique functions; collectively, they provide a set of interrelated services for the Flight Operations Team (FOT) and the IST user community.

Following are descriptions of the eight flight operations services as organized to support the flight operations activity phases:

### Scheduling Phase:

**Planning and Scheduling:** The EOC Schedulers integrates plans and schedules for spacecraft, instruments, and ground operations. They also coordinate multi-instrument observations, if any. The EOC Schedulers utilize a common set of capabilities to perform "what-if" analyses and to visualize plans and schedules.

The PI/TLs can actively participate in the EOS mission planning process through the planning and scheduling tools in the IST toolkit. Included in the toolkit is global visibility into the mission timeline and the set of scheduling products generated at the EOC.

**Command Management:** The Command Management service manages the preplanned command data for the spacecraft and instruments. Based on inputs received from the Planning and Scheduling service, the Command Management service collects and validates the commands, software memory loads, table loads, and instrument memory loads necessary to implement the instrument and spacecraft scheduled activities.

**Real-Time Phase:**

**Command:** The Command service is responsible for transmitting command data (i.e., real-time commands or command loads) to EDOS for uplink to the spacecraft during each real-time contact. Command data can be received in real-time by the operational staff or as preplanned command groups generated by the Command Management service. The Command service is also responsible for verifying command execution on-board the spacecraft.

**Telemetry:** The Telemetry service receives and processes housekeeping telemetry (in CCSDS packets) from EDOS. After the packet decommutation, the telemetry data is converted to engineering units and checked against boundary limits.

**Analysis Phase:**

**Analysis:** The Analysis service is responsible for managing the on-board systems and for the overall mission monitoring. Its functions include performance analysis and trend analysis. It also cooperates with the Telemetry service to support fault detection and isolation.

**Support Services:**

**Resource Management:** The Resource Management service provides the capability to manage and monitor the configuration of the EOC. This includes configuring the EOC resources for multi-mission support; facilitating operational failure recovery during real-time contacts; and managing the real-time interface with the NCC.

**Data Management:** The Data Management service is responsible for maintaining and updating the Project Data Base (PDB) and the EOC history log.

**User Interface:** The User Interface service provides character-based and graphical display interfaces for EOC operators and PI/TLs (using the IST toolkit) interacting with all of the aforementioned flight operations services.

## 3.1 Flight Operations Context Description

The context diagram in Figure 3.1-1 shows the relationship between the EOC and its external interfaces. Figure 3.1-2 shows the relationship between the IST toolkit and its interface with the SCF for importing and exporting microprocessor memory load and dump data, respectively. Table 3.1-1 summarizes the EOC and IST external interfaces, and includes the nominal frequency for each interface item in addition to providing the source and destination of the interface and a description of the data.

There are several notes pertaining to the EOC external interfaces:

- The EOC interfaces with the International Partner Instrument Control Center (IP-ICC) could be applied to any ICC that is external to the EOC at GSFC, even one within the U.S.
- The IST interface to the Science Computing Facility (SCF) is included in this section. The SCF is the facility that provides the hardware where the IST software toolkit resides. However, while every U.S. EOS instrument has an IST software toolkit, not every U.S. EOS instrument has an SCF (e.g., MOPITT instrument on the AM-1 spacecraft) . For simplification reasons, the reference to SCF in this document also includes any PI/TL facility where the IST software toolkit resides. The SCF, in the context of being an interface to the IST, pertains to the PI/TLs software that imports/exports data from flight operations via the IST toolkit.
- The term archive is used in several contexts in this document. The GSFC DAAC provides the long-term storage of flight operations archive data, while the EOC provides the short-term storage of flight operations archive data (nominally data seven days old or less).
- **SMC Interface:** The SMC sends the Long-Term Instrument Plans and the Long-Term Science Plans to the EOC. These sets of plans are produced/updated by the Investigator Working Group (IWG) every six months and cover a period of up to approximately five years. The EOC sends management and operational status information to the SMC.

Note: throughout the remainder of the flight operations concepts discussion in section 3.0 and in Appendix A, reference to the IP-ICC also includes any external ICC.

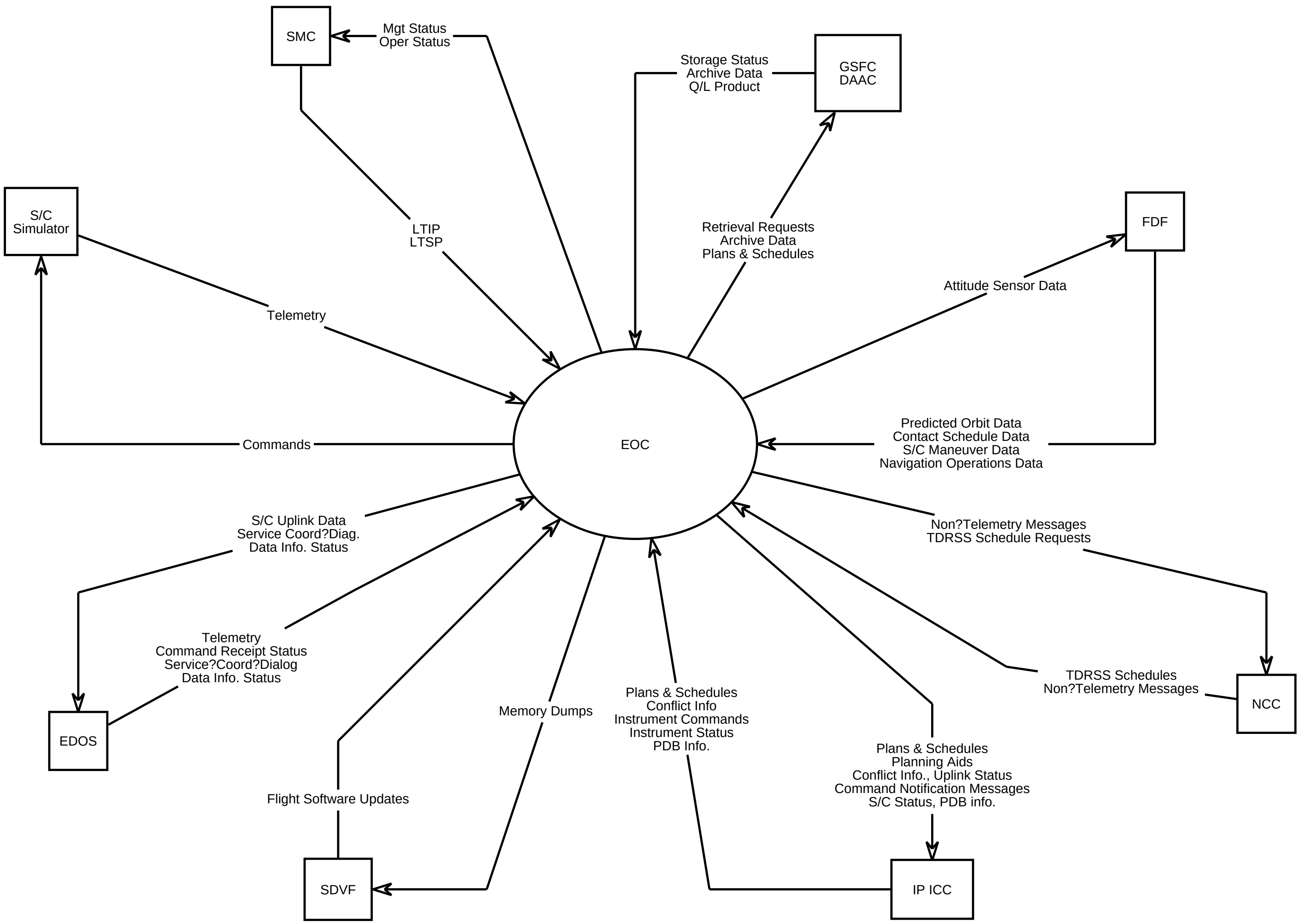



***Figure 3.1-1 EOC External Interface Diagram***

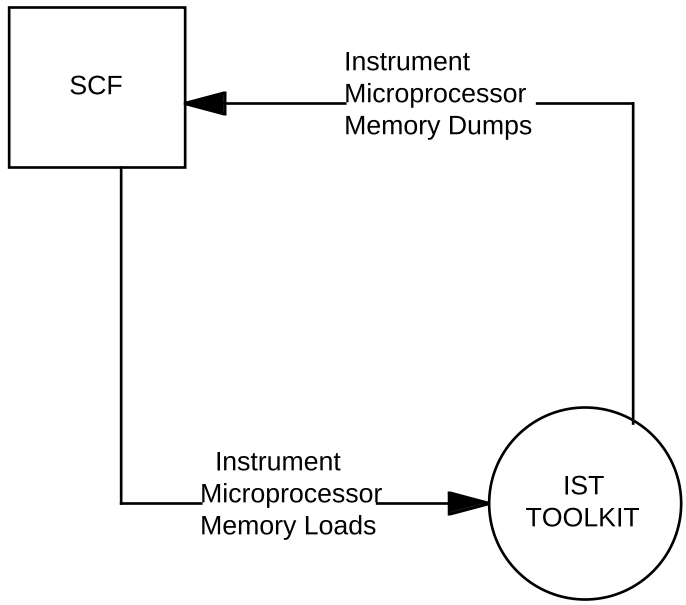



***Figure 3.1-2. IST External Interface Diagram***

- DAAC Interfaces: The GSFC DAAC provides long-term archiving services for the flight operations data. The data sent to the GSFC DAAC includes the spacecraft and instrument housekeeping telemetry, engineering telemetry, event history data, etc. (Note: this data can be retrieved from the GSFC DAAC at a later time.)
- Additionally, the EOC sends mission plans and schedules to the GSFC DAAC.
- The GSFC DAAC also sends engineering products to the EOC, and process requests for flight operations data that has been previously stored in the long-term archive.
- **FDF Interface:** The Flight Dynamics Facility (FDF) sends predicted orbit data to the EOC, which includes predicted ground track data for scheduling purposes. The FDF also sends contact scheduling data such as User Antenna View (UAV) data and Predicted Site Acquisition Tables (PSAT's) to the EOC. The FDF develops plans for spacecraft maneuvers in conjunction with the EOC. The FDF sends the spacecraft maneuver parameters to the EOC. The flight operations schedules and implement these plans. The FDF also sends FDF parameters needed for spacecraft on-board table generation to the EOC. FDF parameters consist of navigational operational parameters and spacecraft maneuver parameters.
- The EOC provides attitude sensor data to the FDF for analysis. This data is a subset of the spacecraft housekeeping telemetry nominally captured by the EOC during a real-time contact. In addition, back orbit telemetry subsets may also be sent to the FDF from the EOC.

- **NCC Interface:** The EOC submits TDRSS schedule requests and non-telemetry messages (e.g., link reconfiguration requests) to the Network Control Center (NCC) . In response, the NCC sends TDRSS schedules notifying the EOC of the status of its request and non-telemetry messages (e.g., TDRSS link status messages, performance data). In the event TDRSS is unavailable, the EOC also interfaces with the NCC to schedule ground station contacts with the contingency network (i.e., Space Network, Ground Network, or Wallops Orbital Tracking Station).

- **IP-ICC Interface:** International Partners (IPs) may provide their own Instrument Control Center (ICC) for their instrument on-board an EOS spacecraft. For example, Japan will provide an IP-ICC for the ASTER instrument on-board the AM-1 spacecraft. The IP-ICC provides instrument plans and schedules to the EOC, and coordinates scheduling conflicts with the EOC when they arise. The EOC sends planning aids, integrated mission plans and schedules to the IP-ICC for analysis to refine instrument scheduling, and also receives scheduling conflict information from the EOC.

  An IP-ICC can send instrument commands to the spacecraft via the EOC. The EOC validates each command sent from an IP-ICC and builds the command bit pattern. The EOC sends the command to the spacecraft via the EDOS interface. The EOC reports on the uplink status to the IP-ICC. In addition, the EOC can send commands to the spacecraft on behalf of the instrument (e.g., to safe the instrument). The EOC notifies the IP-ICC with a command notification message in this situation.

  An IP-ICC can send instrument data base update requests to the EOC. After the data base update request has been approved, or whenever a new project data base has been established in the EOC, the updated project data base will be sent to the IP-ICC.

  Periodically, the EOC sends mission status information to the IP-ICC, and the IP-ICC sends instrument status to the EOC.

- **SDVF Interface:** The Software Development and Validation Facility (SDVF) sends flight software loads to the EOC. These loads are scheduled by the EOC for subsequent uplink to the spacecraft. The EOC may send memory dumps to the SDVF.

- **EDOS Interface:** EDOS provides the EOCs interface with the SN, DSN, GN, and WOTS for spacecraft commanding and telemetry operations. The EOC sends spacecraft uplink data, including spacecraft and instrument commands and command loads, to the spacecraft via the EDOS interface. EDOS, in turn, provides the EOC with spacecraft command receipt status.

  EDOS sends spacecraft and instrument housekeeping telemetry in real-time from the spacecraft to the EOC. This data will be used by the FOT to monitor the health and safety of the spacecraft and instruments during real-time contacts, and to perform command verification.

  EDOS also sends back-orbit housekeeping telemetry from the spacecraft to the EOC. This data will be sent via the rate-buffered service that EDOS provides after a contact has been completed.

Service coordination dialogue messages and data interface status messages are also sent between the EOC and EDOS.

- **Spacecraft Simulator Interface:** The EOC sends spacecraft and instrument commands to the Spacecraft Simulator. The Spacecraft Simulator sends simulated spacecraft telemetry to the EOC. This interface is provided for the purpose of flight operations training and development, and validation of operational procedures.
- **SCF Interface:** Microprocessor memory loads for instruments can be submitted to the EOC via the IST toolkit from the SCF. These microprocessor memory loads are scheduled by the EOC for subsequent uplink to the spacecraft. The EOC sends microprocessor memory dumps to the SCF via the IST toolkit. The SCF also has a general interface with the EOC via the IST toolkit to import and export other data (e.g., telemetry data files).

***Table 3.1-1. Flight Operations External Interfaces (1 of 3)***

| Source | Destination | Data Description | Frequency |
|---|---|---|---|
| SMC | EOC | LTIP | every 6 months |
| SMC | EOC | LTSP | every 6 months |
| EOC | SMC | Management status | as required |
| EOC | SMC | Operational status | as required |
| EOC | DAAC | Archive data | daily for long-term storage |
| EOC | DAAC | Plans and Schedules | daily |
| DAAC | EOC | Storage status | for each long-term storage request |
| EOC | DAAC | Retrieval request for long-term flight operations data in long-term archive | as requested primarily for analysis |
| DAAC | EOC | Archive data | as requested primarily for analysis |
| DAAC | EOC | Engineering product | as requested (very infrequent) |
| FDF | EOC | Predicted orbit data | daily/weekly |
| FDF | EOC | Contact schedule data | daily/weekly |
| FDF | EOC | Spacecraft maneuver data | nominally every 45 days |
| FDF | EOC | Navigation operations data | daily |
| EOC | FDF | Attitude sensor data | each spacecraft contact |

**Table 3.1-1. Flight Operations External Interfaces (2 of 3)**

| Source | Destination | Data Description | Frequency |
|---|---|---|---|
| NCC | EOC | TDRSS schedules | weekly/ daily updates |
| NCC | EOC | Non-telemetry messages | each TDRSS contact |
| EOC | NCC | TDRSS schedule requests | weekly/ daily updates |
| EOC | NCC | Non-telemetry messages | each TDRSS contact |
| IP-ICC | EOC | Plans and schedules | daily |
| IP-ICC | EOC | Conflict info | nominally daily |
| IP-ICC | EOC | Instrument commands | infrequent; based on mission requirement |
| IP-ICC | EOC | Instrument status | weekly |
| IP-ICC | EOC | Data base information | nominally every 3 months |
| EOC | IP-ICC | Plans and schedules | daily |
| EOC | IP-ICC | Planning aids | daily/weekly |
| EOC | IP-ICC | Conflict info | as applicable |
| EOC | IP-ICC | Uplink status | each IP-ICC command sequence |
| EOC | IP-ICC | Command notification messages | each unplanned IP-ICC command issued from EOC |
| EOC | IP-ICC | Spacecraft status | weekly |
| EOC | IP-ICC | Data base information | nominally every 3 months |
| SDVF | EOC | Flight software updates | infrequent 4/year |
| EOC | SDVF | Memory dumps | as requested 4/year |
| EDOS | EOC | Telemetry | each spacecraft contact |
| EDOS | EOC | Command receipt status | each command sequence |
| EDOS | EOC | Service coordination dialogue | prior to spacecraft contact |
| EDOS | EOC | Data information status | periodically during each spacecraft contact |
| EOC | EDOS | Spacecraft uplink data | each command sequence |

*Table 3.1-1. Flight Operations External Interfaces (3 of 3)*

| Source | Destination | Data Description | Frequency |
|---|---|---|---|
| EOC | EDOS | Service coordination dialogue | each spacecraft contact |
| EOC | EDOS | Data information status | each spacecraft contact |
| Spacecraft Simulator | EOC | Telemetry | as required; nominally infrequent |
| EOC | Spacecraft Simulator | Commands | as required; nominally infrequent |
| SCF | IST | Instrument Microprocessor Memory Load | as required; nominally infrequent |
| IST | SCF | Instrument Microprocessor Memory Dump | as required; nominally infrequent |

## 3.2 Flight Operations Staff

While the previous section focused on the functional interfaces between the EOC and the IST and their externals, this section focuses on describing the flight operations team and their functional responsibilities. This serves as background material for the next subsection, which describes the flight operations concepts through operational scenarios. In particular, these scenarios describe many of the names of flight operation roles delineated in this subsection.

Note: this subsection identifies the flight operations roles and is not intended to identify a specific number of operational positions. For instance, one person may fulfill two or more operational roles described herein, and vice-versa. The intent of this subsection is to delineate operational roles and tasks.

Descriptions of the FOT tasks fall into four categories: management, management support, off-line and on-line. The management roles are: EOC Manager, Flight Segment Engineer, and Flight Operations Manager. The management support roles are: Training Coordinator, Administration, Configuration Management, Performance Assurance and Operations Coordinator. The off-line roles are Off-Line Engineer, Mission Planner/Scheduling Supervisor, and Scheduler. The on-line roles are: Operations Controller, Command Activity Controller, Spacecraft Evaluator, Instrument Evaluator, and Ground Controller.

### 3.2.1 Management Roles

#### 3.2.1.1 EOC Manager

The EOC Manager has primary responsibility for the safe and consistent operation of the EOC including the EOC technical and management functions. The EOC Manager consults with the

Flight Operations Director, Mission Operations Manager the Flight Project Operations Manager, and the Project Scientist or designee as necessary in the resolution of conflicts.

#### 3.2.1.2 Flight Segment Engineer

The Flight Segment Engineer (FSE) is responsible for the overall health and safety of the EOS spacecraft. The FSE provides direction to the off-line and on-line engineering staff, leads in the development of spacecraft command procedures, leads anomaly resolution teams, and is responsible for the integrity of the ECS databases.

#### 3.2.1.3 Flight Operations Manager

The Flight Operations Manager is responsible for the daily EOC operations and mission support, and is responsible for the management of EOC resources. The Flight Operations Manager provides direction for the scheduling activities, working with the Flight Segment Engineer and the Operations Coordinator to ensure smooth and safe EOC operations.

### 3.2.2 Management Support Roles

#### 3.2.2.1 Training Coordinator

The Training Coordinator is responsible for the implementation of the training plan, ensuring that the FOT is properly trained.

#### 3.2.2.2 Administration

This role provides the administrative and secretarial duties for the FOT and is responsive directly to the EOC Manager.

#### 3.2.2.3 Configuration Management

FOS Configuration Management has the responsibility of approving configuration management procedures with upper management, ensuring that changes to EOC hardware, software, and procedures are properly documented and coordinated, assists with the development and maintenance of the FOS library, coordinates Requests for Information Disposition (RID) requests generated during FOS Maintenance and Operations reviews, and generates monthly Configuration Control Board (CCB) reports.

#### 3.2.2.4 Performance Assurance

Performance Assurance (PA) is responsible for assisting the EOC management in monitoring, reviewing, and providing input to FOS M&O generated documents and reviews. PA is also responsible for monitoring and recording M&O requirements satisfaction during all M&O simulations and tests involving EOS spacecraft.

### 3.2.3 Off-Line Roles

#### 3.2.4.1 Off-Line Engineer

The Off-Line Engineers are responsible for the health and safety of one or more spacecraft subsystems and/or instruments. Responsibilities for the assigned subsystem(s) and/or instrument(s) include: routine operation and management, supporting command procedure development, generating and reviewing performance and trend analysis, supporting testing, and supporting anomaly resolution teams. It is assumed that a substantial part of the off-line engineering work for the instruments will be done at the ISTs by the PI/TL. Specific responsibilities can be negotiated on a per-instrument basis.

#### 3.2.4.2 Mission Planner/Scheduling Supervisor

The Mission Planner/Scheduling Supervisor is responsible for the overall EOC scheduling activities and scheduling personnel. The Mission Planner/Scheduling Supervisor leads in the development of conflict resolution procedures, supports development of scheduling activities, provides direction to the EOC scheduling personnel, and is the point of contact for the project scientist when the project scientists needs to make conflict resolution decisions.

#### 3.2.4.3 Scheduler

The Scheduler performs EOC spacecraft and instrument resource scheduling. The responsibilities of the Scheduler include: generating long-term spacecraft operations plans based upon inputs from the off-line engineers, creating baseline activity profiles based upon PI/TL input and the LTIP, initial scheduling to establish NCC TDRSS contact times over a target week, final scheduling, conflict resolution, TOOs and late changes, feeding the final detailed activity schedule into CMS, and generating the integrated loads and the ground scripts using the CMS. The Scheduler has responsibility for the scheduling of shared resources, including spacecraft platform subsystems such as attitude control, command and data handling, thermal and power, etc.

#### 3.2.2.4 Operations Coordinator

The Operations Coordinator assists the EOC management in the areas of configuration management, project database maintenance, EOC ground system anomalies, and EOC software updates that involves the FOS software development organization. The Operations Coordinator schedules all ground system tests and simulations that involve EOS spacecraft.

### 3.2.4 On-Line Roles

#### 3.2.4.1 Operations Controller (shift)

The Operations Controller is the lead position on shift, supervising all real-time spacecraft commanding and data capture activities. The Operations Controller is responsible for shift briefings and debriefings, interfaces to external and internal elements, coordinates real time scheduling changes, approves real time command uplink, leads anomaly resolution, monitors the activity timeline, maintains the shift log, generates management reports, and represents EOC management during non prime shifts.

#### 3.2.4.2 Command Activity Controller (shift)

The Command Activity Controller (CAC) is responsible for all real-time command initiation and verification. The CAC supports all real-time data capture, and is responsible for: pre-contact ground system configuration; for post-contact data playback and archival; activates and monitors the ground script; monitors the performance data; assists the spacecraft and instrument evaluators; and debriefs the operations controller.

#### 3.2.4.3 Spacecraft Evaluator (shift)

The Spacecraft Evaluator performs the real-time spacecraft bus command and telemetry monitoring and analysis. The spacecraft evaluator is responsible for the spacecraft anomaly detection and contingency procedure execution, all routine spacecraft command load validation, provides technical support to the Operations Controller and the Command Activity Controller, and performs routine spacecraft performance and trend analysis.

#### 3.2.4.4 Instrument Evaluator (shift)

The Instrument Evaluator performs the real-time instrument command and telemetry monitoring and analysis. The Instrument Evaluator is responsible for the instrument anomaly detection and contingency procedure execution, routine instrument command load validation, provides technical support to the Operations Controller and the Command Activity Controller, and performs routine instrument performance and trend analysis.

#### 3.2.4.5 Ground Controller (shift)

The Ground Controller is responsible for EOC systems administration, data management, and for supporting engineering, configuration management and data entry tasks.

## 3.3 Flight Operations Scenarios

The operational scenarios delineated in this subsection provide a representative discussion of the flight operational concepts and functional requirements. The operational scenarios illustrate how the flight operations services are integrated to fulfill the disparate requirements of the flight operations staff and the PIs/TLs. A detailed, comprehensive discussion of flight operational concepts is included in Appendix A, the Flight Operations Concept.

Planning, scheduling, commanding, and telemetry monitoring of the EOS spacecraft will be performed on a spacecraft-by-spacecraft basis by the Flight Operations Team (FOT). Parallel but separate configurations (e.g., data bases, schedules, commands, and archive files) will be maintained for each EOS spacecraft. The Command Activity Controller position executes the ground script that sends commands and command loads to the spacecraft. Constraints are checked to ensure that only the single authenticated Command Activity Controller position has authority to send commands to the spacecraft. This approach facilitates the concurrent support of multiple spacecraft with different science goals and overlapping TDRSS contacts.

The health and safety of multiple instruments can be monitored by a single Instrument Evaluator. This operational approach can be efficiently performed due to the nature of the instruments, which are primarily non-complex.

The separate configuration approach also is applied to the replacement of an EOS spacecraft within a series. For example, separate configurations are maintained for the AM-1 and AM-2 spacecraft. Similarly, this approach is applied to enable the FOT to perform on-going support of spacecraft in-orbit and spacecraft in the operations testing phase. Flight Operations can be configured so that support for multiple spacecraft in-orbit is physically separated from the operations associated with spacecraft in the operations testing phase. This capability provides an additional level of control and security to flight operations.

The block diagram in Figure 3.3-1 outlines the different groups of personnel involved in Flight Operations, their applicable functional area(s), and their external interfaces. For instance, the Spacecraft Evaluator monitors the telemetry housekeeping data, identifies anomalies, and issues problem reports, as applicable. A more detailed discussion of each of the FOT roles and their corresponding responsibilities was previously included in Section 3.2.

Figure 3.3-1, as well as the operational scenarios described in the remainder of this section, are partitioned into four primary areas: planning and scheduling, command management, real-time command and telemetry, and spacecraft and instrument analysis.

The Planning and Scheduling services coordinate and integrate instrument and spacecraft bus command and control requests. It requires the cooperative effort between the Flight Operations planning and scheduling staff, the instrument planning and scheduling staff, and the PI/TL representatives. The PI/TLs interact with the EOC Schedulers to ensure that their instruments are configured to collect the desired science data and ensure the quality of their instruments. These requests are submitted to the EOC Schedulers in the form of activity requests. The EOC Schedulers constraint check the activity requests, assign priorities, and develop a schedule of activities for the instrument. The EOC Schedulers, configure the spacecraft bus subsystems to efficiently use spacecraft resources and execute orbital maneuvers. In addition, the EOC Schedulers integrate the instrument and spacecraft subsystem activities (i.e., the detailed activity schedule) into an overall schedule. The final schedules are available to the PI/TLs via their IST.

The Command Management services use the detailed activity schedule previously developed to generate the ground scripts that are used during a real-time contact with the spacecraft to send commands and command loads (including SCC loads and microprocessor memory loads) to the spacecraft. The EOC Scheduler integrates this command data with the spacecraft subsystem commands, command loads into a ground script. In addition to the command data, the ground script includes the directives required to configure flight operations to support the pre-contact, contact, and post-contact operations (e.g., load the correct data base).

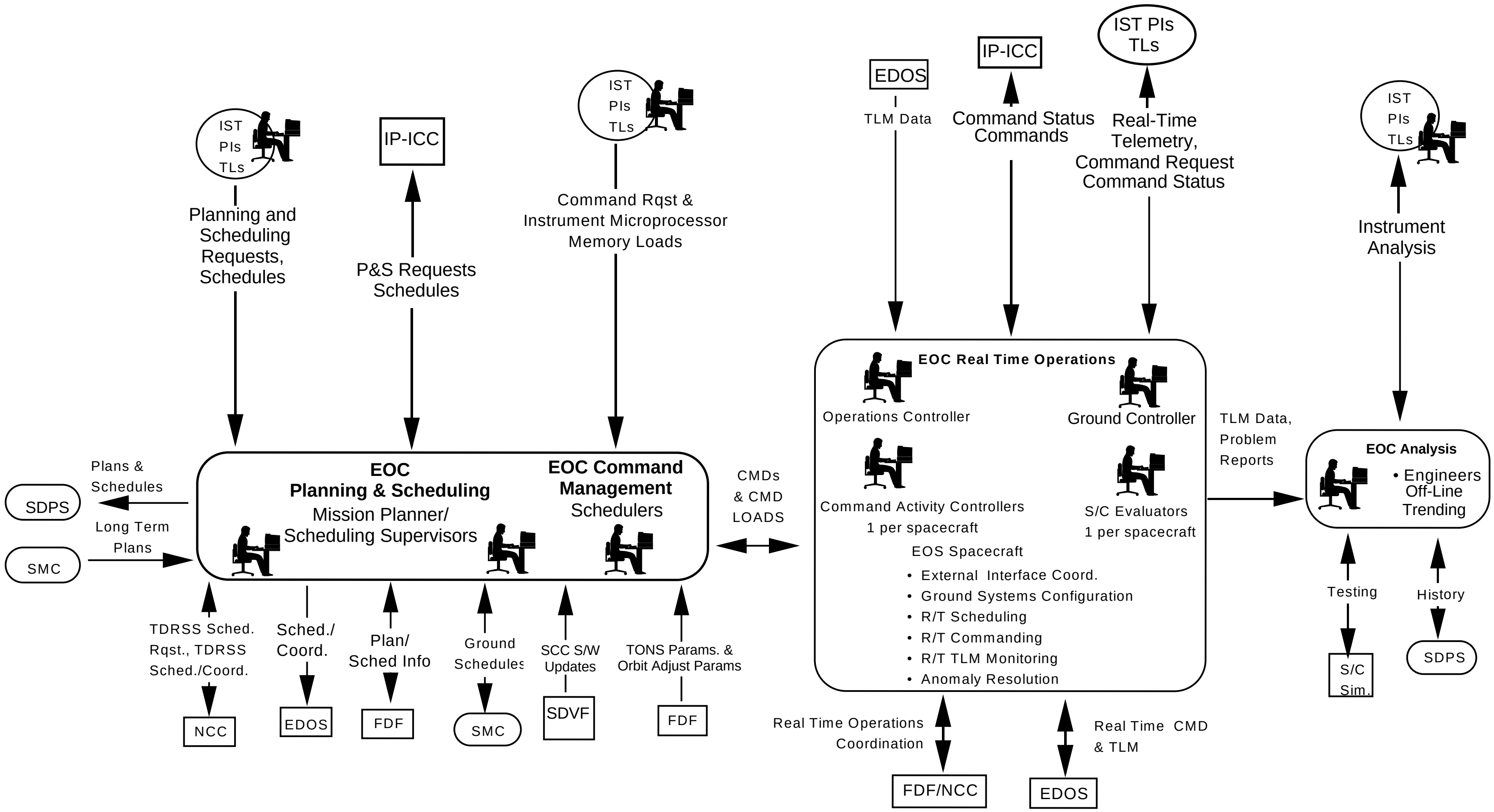



*Figure 3.3-1. Flight Operations' System Level Concepts*

The Command and Telemetry services provide the Command Activity Controllers the ability to execute the ground script generated for that day's activities by the EOC Schedulers. The Command Activity Controllers verify that the stored commands are successfully loaded on-board the spacecraft for subsequent execution, as well as the loading and execution of real-time commands. The Spacecraft Evaluators monitor the telemetry housekeeping data downlinked from the spacecraft. In parallel, the instrument housekeeping and engineering telemetry are monitored by the Instrument Evaluators at the EOC and/or PI/TL at the IST. An operational concept highlighted in this area is the concurrent real-time operations of commanding and monitoring multiple spacecraft.

While Spacecraft Evaluators focus on identifying and resolving spacecraft and/or instrument anomalies during real-time, FSE and Off-Line Engineers review telemetry trend data to identify and resolve spacecraft degradation and resource problems. The Spacecraft Analysis services provide the Spacecraft Engineers with the tools to identify potential and actual problems so that a pre-emptive or corrective action plan can be implemented. For instance, a battery monitoring tool may indicate a battery degradation problem. The Spacecraft Engineer would modify operational procedures vis-a-vis the battery. This corrective action would modify the operational environment of the battery.

### 3.3.1 Planning and Scheduling Scenario

The objective of planning and scheduling is to produce an integrated schedule of activities for the instruments and spacecraft subsystems. The process has a distributed architecture, allowing for input from the external science community. In addition, the distributed design permits a separated network of principal investigators (PIs) and/or team leaders (TLs) to have direct input into the planning and scheduling of their instruments. As shown in Figure 3.3.1-1, planning and scheduling has three primary components: long-term planning, initial scheduling and final scheduling.

#### 3.3.1.1 Long-Term Planning

The project scientist is involved in every aspect of long-term planning, which involves the development of plans related to science objectives, instrument operations and spacecraft operations. Approximately every six months, scientists and other technical members of the IWG meet with the project scientist to develop a Long Term Science Plan (LTSP) that defines the primary science objectives of the EOS spacecraft and instruments for the next five years. Using input from the LTSP, the PI/TL for an instrument works with the project scientist to develop a Long Term Instrument Plan (LTIP). An LTIP is also a five year plan that includes instrument-specific details on collections, maintenance and calibrations. The LTSP and LTIPs establish the framework for the collections performed by the EOS spacecraft. The EOC receives the LTSP and LTIPs via the System Monitoring and Coordination (SMC).

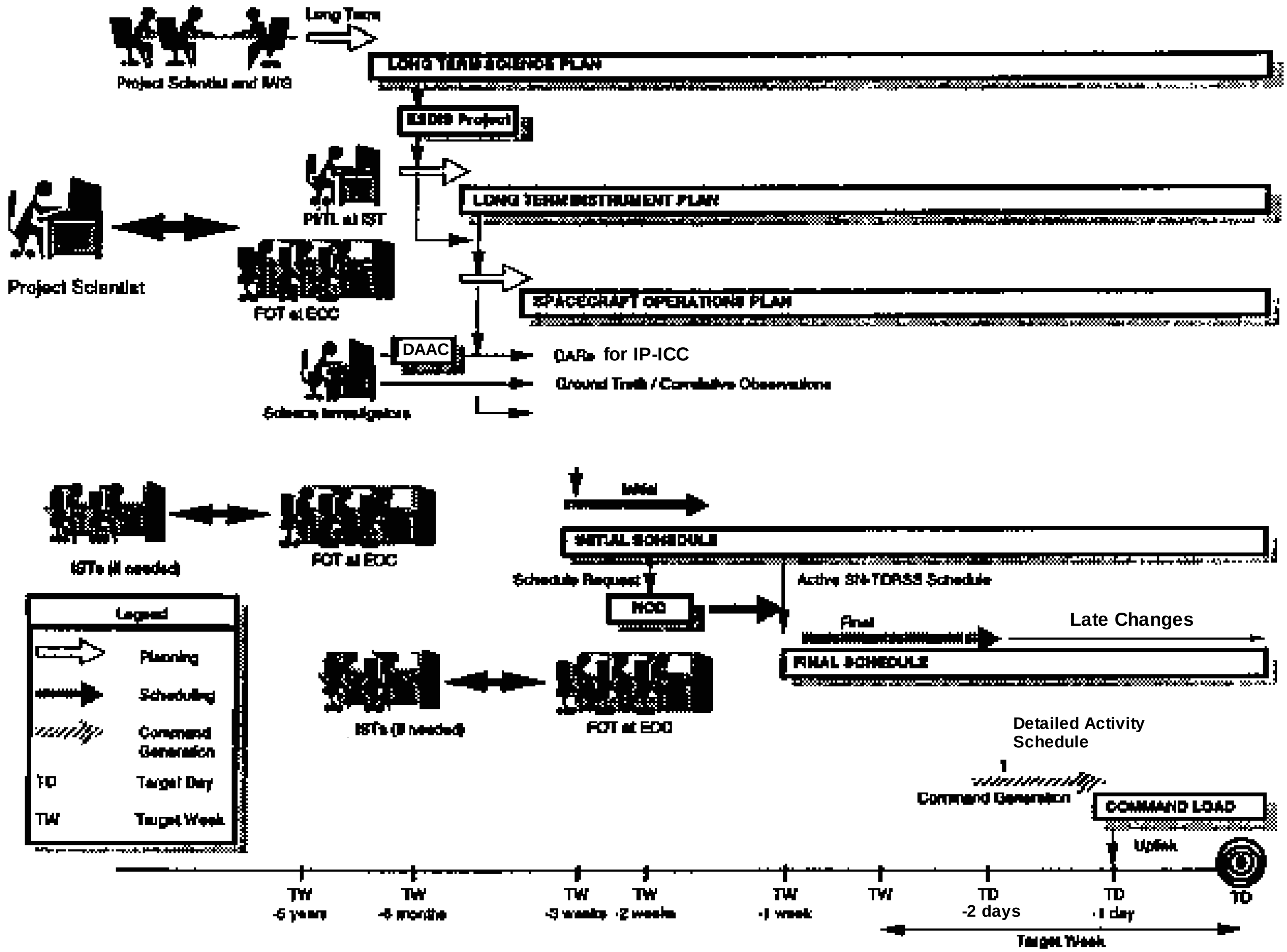



*Figure 4.3.1-1. Planning and Scheduling Process*

The final long-term spacecraft plan is developed with input from the Off-Line Engineers of the Flight Operations Team (FOT). In conjunction with the project scientist, a long-term spacecraft operations plan is developed by the EOC scheduler using the LTSP and LTIPs. The long-term spacecraft operations plan outlines anticipated subsystem operations and maintenance, along with forecasted orbit maneuvers from the Flight Dynamics Facility (FDF). The FDF also supplies the EOC with propagated spacecraft ephemeris needed for planning and scheduling.

With all three long-term plans developed, the EOC/ISTs can produce a Baseline Activity Profiles (BAP) for their non-complex instruments. A BAP is a schedule of activities corresponding to normal instrument operations. Simple instruments rarely deviate from their BAP, and their scheduling process is often complete at this stage. However, the more complex an instrument, the more frequent are the deviations that occur. In addition, true complex instruments do not have BAPs because their scheduled activities significantly vary due to criteria. The scheduling of deviations to BAPs, along with the scheduling of more complex instruments, is dependent upon available resources, with the most important being TDRSS contact times. The objective of initial scheduling is to allocate these communication times through the NCC.

#### 3.3.1.2 Initial Scheduling

For some U.S. EOS instruments, on a pre-negotiated basis, the PI/TL of the IST predicts their instruments' resource requirements. For the remaining EOS instruments, the instrument scheduler at the EOC predicts the instruments' resource requirements. IP-ICCs are also involved in initial scheduling by providing the EOC with the necessary resource information. With this information, the EOC can negotiate with the NCC for TDRSS contact times.

U.S. EOS instruments have a BAP developed during the long-term planning process. The PI/TL at the IST determines if the BAP for the target week is acceptable. Being deemed adequate, all scheduling for the target week would be complete, and no further actions would be taken. However, a decision to modify the BAP may arise from recent collection requirements, instrument support activities and spacecraft activities that impact the instrument. The EOC Scheduler in coordination with the PI/TL at the IST develops deviations to the BAP (based on a pre-negotiated basis). The EOC is responsible for constraint checking any resource deviations and getting PI/TL approval for the resource deviations prior to submitting the deviation list to the EOC Scheduler for all instruments assigned to it. Similarly, the PI/TL at the IST is responsible for constraint checking any resource deviations prior to submitting the deviation list to the EOC Scheduler if primary planning and scheduling responsibility has been assigned to the PI/TL. The PI/TL participates in the planning and scheduling process through their IST system. Three weeks before the target week, the EOC Scheduler merges the deviation lists with their corresponding BAPs to generate the instrument resource profiles, representing the instruments' resource needs over the target week.

IP-ICCs have the capability to interface with the EOC during all phases of schedule development. During initial scheduling, the IP-ICC develops an instrument resource profile that details instrument resource needs. The EOC scheduler receives this profile three weeks before the start of the target week.

Like the instruments, spacecraft subsystems also require certain resources during operation. To account for their resource needs, the EOC Scheduler at the EOC performs the necessary analyses and generates the spacecraft subsystem resource profile based upon inputs from the off-line engineers.

With the resource profiles for the instruments and spacecraft subsystems, the EOC Scheduler integrates them together to determine the overall spacecraft and instrument resource requirements for the target week. Based on these resource needs, the EOC Scheduler formulates the desired TDRSS contact times and submits them to the NCC. If the requested times are not allocated by the NCC, the EOC may negotiate with the NCC for the best available TDRSS contact periods. Negotiations can take place until one week before the target week, when the NCC provides the active TDRSS schedule to the EOC.

Approximately one week before the target week, the EOC Scheduler incorporates the NCC's TDRSS times into a preliminary resource schedule and send it to the ISTs and the IP-ICC. If modifications were made to the original instrument resource profiles, notification of the changes, along with a reason, is also being sent to the appropriate IST. With the TDRSS contact times, the PIs/TLs and EOC Scheduler has the necessary information to begin final scheduling.

#### 3.3.1.3 Final Scheduling

The final scheduling phase begins one week prior to the target week. The EOC Scheduler in coordination with the PI/TL at the IST, or the PI/TL at the IST, develops a list of activities required for the instrument based on maintenance activities, calibrations, and/or spacecraft activities. For U.S. EOS instruments, an activity deviation list is created. The EOC Scheduler is responsible for constraint checking the activities and getting PI/TL approval prior to forwarding the activity list to the EOC Scheduler, for all instruments assigned to it. Similarly, the PI/TL at the IST is responsible for constraint checking the activities prior to forwarding the activity list to the EOC Scheduler, if primary planning and scheduling responsibility has been assigned to the PI/TL. For IP-ICCs, activity lists are created and submitted to the EOC.

The EOC Scheduler integrates all the instrument and spacecraft activities and performs conflict resolution to produce a detailed activity schedule. The EOC Scheduler notifies the instrument EOC Scheduler or the PI/TL at the IST of any activities that were rejected due to conflict. The EOC Scheduler or the PI/TL at the IST decides on resubmitting the rejected activities or rescheduling them on a future target day, if possible. IP-ICC Schedulers are also be notified of scheduling conflicts, allowing activities to be resubmitted if desired.

During the final scheduling process, a certain amount of analysis and coordination may take place to incorporate activities into the detailed activity schedule. Figure 3.3.1-2 presents a functional example of the IST and EOC during final scheduling constraint resolution. The scenario assumes the primary instrument planning and scheduling role has been established at the EOC based upon a pre-negotiated basis.

An example of an IST scheduling request might be a request to place the instrument in a calibration mode over a specified time period. A description of the steps in Figure 3.3.1-2 are shown below. Steps with the same number and "a" or "b" indicate either of these paths could occur at this point.

1. The PI/TL at an IST decides to send a modification to the preliminary resource schedule. Using analysis tools such as a map display, the PI/TL can check for target/region visibility, potential scheduling opportunities and other types of data. The request is sent to the instrument EOC Scheduler for further analysis and incorporation into the instrument schedule. In addition, the PI/TL may include a certain degree of flexibility in the request, such as various collection times.

2. The instrument EOC Scheduler receives the request from the IST. After inspection, the instrument EOC Scheduler may contact the PI/TL for clarification. The instrument EOC Scheduler performs a variety of analyses, including conflict resolution, resource availability and science assessment. Constraint checking is instrument specific, leaving the more detailed inter-instrument and subsystem constraint modeling to the spacecraft EOC Scheduler. However, the instrument EOC Scheduler does have the capability to submit “what-if” schedules for analysis purposes. Based on the available resources and activity conflicts, the instrument EOC Scheduler establishes a schedule priority for the activity.

3a. If the instrument EOC Scheduler cannot schedule the request, the IST is notified along with an explanation. At this point, the PI/TL may decide to modify the request for EOC acceptance.

3b. If the instrument EOC Scheduler accepts the IST’s request, it is included in the instrument activity deviation list.

4. The spacecraft EOC Scheduler integrates the list with those received from the other instruments, including the spacecraft subsystems’ activity lists. This allows the spacecraft EOC Scheduler to analyze overall resource availability and investigate any health and safety constraints that affect the spacecraft or instruments. The resource model at the EOC includes the modeling of inter-instrument constraints (e.g., jitter or electromagnetic interference) and subsystem constraints (e.g., data volume). The spacecraft EOC Scheduler attempts to overcome constraints by using any provided flexibility in the activities. If the spacecraft EOC Scheduler cannot resolve a scheduling conflict, the Project Scientist at the EOC has the final decision.

5a. The spacecraft EOC Scheduler accepts the PI/TL's request. The spacecraft EOC Scheduler includes the activity in the detailed activity scheduler that will be used for command generation.

5b. The spacecraft EOC Scheduler discovers a constraint conflict with the PI/TL's request. Therefore, it is not included in the detailed activity schedule, and an explanation for the non-acceptance is sent to the PI/TL and instrument EOC Scheduler.

6a. Upon notification of rejection, the instrument EOC Scheduler contacts the PI/TL at the IST, and they decide to reschedule the activity on a later target day, if possible.

6b. Upon notification of rejection, the instrument EOC Scheduler contacts the PI/TL at the IST, and they decide to rework the activity for the given target day. Based on the reason for rejection, the PI/TL may modify certain details of the request. These may include the desired collection times or the collection areas. Using the modified activity, the instrument EOC Scheduler once again performs the necessary analyses to check instrument constraints and resources. At this stage, the instrument EOC Scheduler may desire to check the detailed inter-instrument and subsystem constraints. To accomplish this, "what-if" analysis is performed for checking the overall impact of the modified activity. Once the instrument EOC Scheduler develops an acceptable compromise, the PI/TL is contacted for approval, and it is resubmitted to the spacecraft EOC Scheduler in the instrument activity deviation list.

7. The spacecraft EOC Scheduler receives the instrument activity deviation list that includes the PI/TL's modified activity. As before, the spacecraft EOC Scheduler analyzes the overall resources and constraints, with assistance from the Project Scientist, if necessary.

8a. This time, the spacecraft EOC Scheduler discovers a different constraint conflict associated with the PI/TL's request. Therefore, it is not included in the detailed activity schedule and an explanation for the non-acceptance is sent to the PI/TL and instrument EOC Scheduler. If there is still allowable time, the instrument EOC Scheduler and PI/TL may once again decide to rework the request for acceptance (step 6b). The constraint resolution procedure will occasionally require multiple iterations.

8b. The spacecraft EOC Scheduler accepts the PI/TL's modified request. The spacecraft EOC Scheduler includes the activity in the detailed activity schedule that will be used for command generation.

Approximately two days before the target day, the EOC sends the detailed activity schedule to the ISTs and IP-ICCs. Late changes (including Targets of Opportunity (TOOs) from a complex instrument IP-ICC) are still being accepted up to 24 hours before an observation. Between 24 hours and 6 hours of an observation, a late change is being accepted for possible implementation if it does not affect the previously scheduled activities. Within 6 hours before the observation to 1 hour before the last TDRSS contact prior to the observation, the late change is accepted if it requires only real-time commands. The Mission Operations Manager assigns the responsibility of verifying that real-time command changes have no effect on the spacecraft and instrument health and safety to a Flight Operations Director. For historical purposes, all activity changes are described in the detailed activity history log.

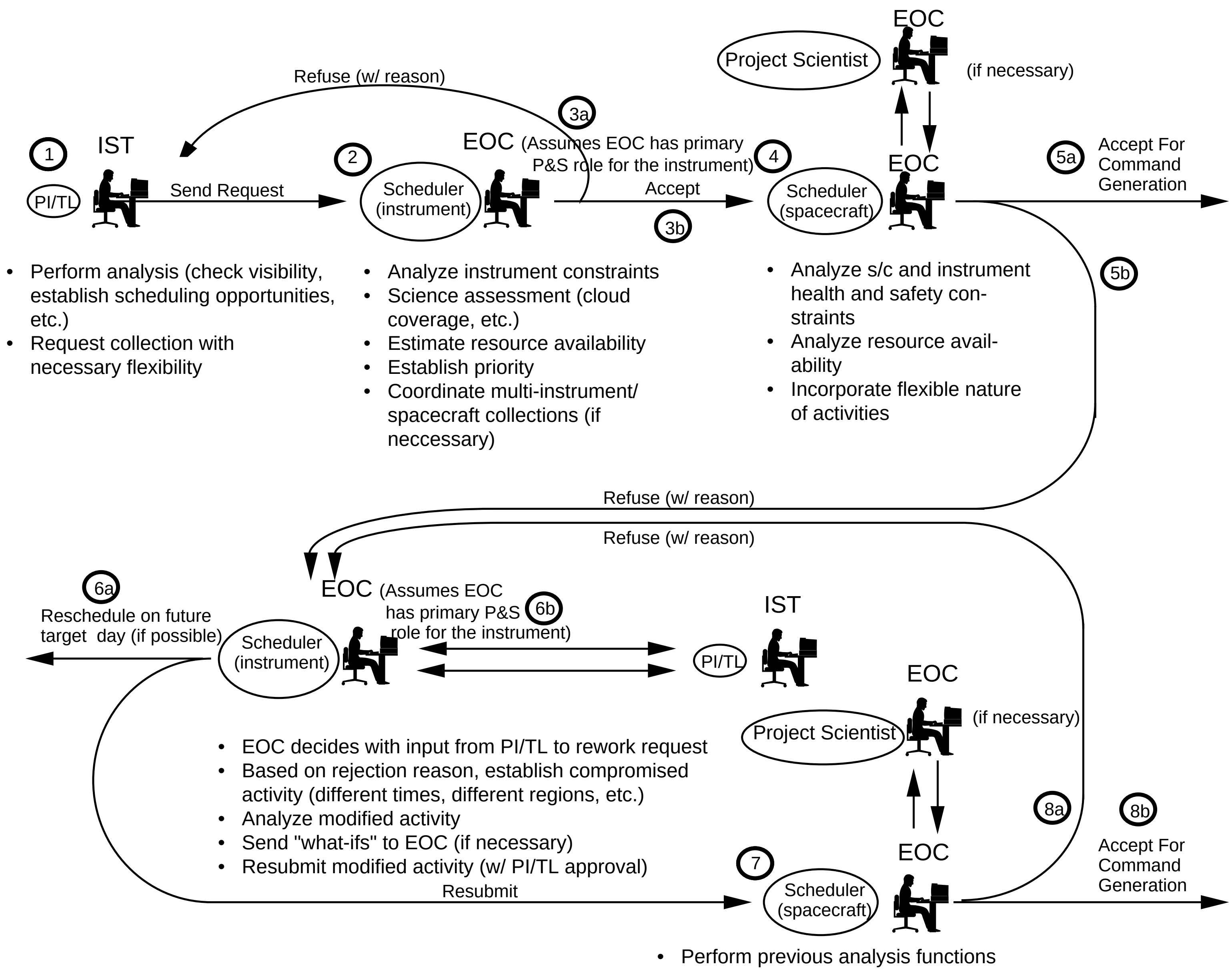



***Figure 3.3.1-2. Final Scheduling Constraint***

### 3.3.2 Command Management Scenario

The normal procedures for command and control of the EOS spacecraft and instruments are based upon the detailed activity schedule which is generated by the FOS Planning and Scheduling service. The Command Management service is that portion of the FOS which is responsible for translating activities in the detailed activity schedules into Spacecraft Control Computer (SCC)-stored instrument commands, SCC-stored instrument loads, instrument micro-processor loads, SCC-stored spacecraft commands, SCC-stored spacecraft table and ground scripts. The combination of these commands and tables, as well as the SCC software updates provided by the spacecraft contractor, are uplinked to the EOS spacecraft during the appropriate TDRSS contact.

NOTE: The ground script consists of time stamped directives for the EOC to process the current day's contact periods. The directives include ground directives and real-time spacecraft commands, spacecraft loads and instrument microprocessor loads.

The following scenario, depicted in Figure 3.3.2-1, describes the role of the EOC and IST Schedulers in nominal operations. Inputs to this scenario include: the detailed activity schedule generated by the Planning and Scheduling service; orbital data provided by the Flight Dynamics Facility (FDF); instrument flight software provided by the PI/TL and spacecraft flight software provided from the SDVF. Outputs from this scenario include a spacecraft load ground script for use in real-time operations.

1. Approximately two days prior to the target day, both the EOC and the PI/TL at the IST receive the detailed activity schedule from the Planning and Scheduling service.
2. For some instruments, on a pre-negotiated basis, the PI/TL at the IST is responsible for the generation and validation of their instrument microprocessor loads and instrument commands (note: generation and validation of the instrument flight software loads remain the responsibility of the PI/TL using non-ECS tools). For the remaining instruments, the EOC Scheduler is responsible for the generation and validation of instrument microprocessor loads and instrument commands. The generated commands are validated to ensure that they do not violate any operational constraints of the instrument.
3. The instrument commands and instrument microprocessor loads are sent to the EOC to be incorporated into the ground script.

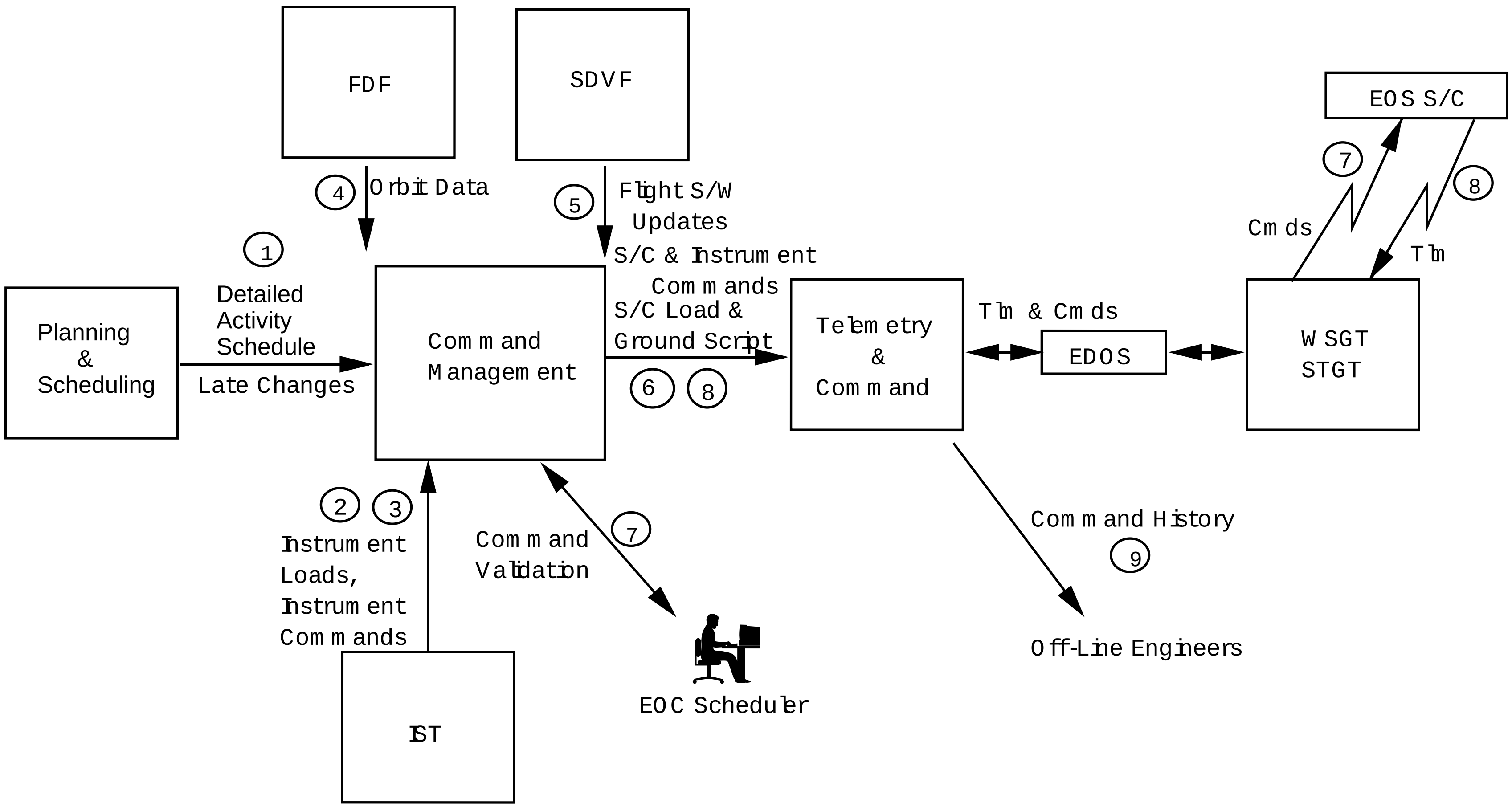



*Figure 3.3.2-1. Command Management*

4. The FDF provides the EOC with orbit adjustment data and TDRSS Onboard Navigation System (TONS) information.
5. As required for spacecraft operations, the spacecraft builder supplies the EOC with any updates to the spacecraft's flight software.

6a. The EOC Scheduler generates spacecraft commands and spacecraft tables based on the detailed activity schedule.

6b. Additionally, the EOC Scheduler generates instrument commands and tables for International Partners (IPs) based on the IPs command requests and instrument databases. (This allows the FOS to ensure spacecraft health and safety.)

7a. The EOC Scheduler validates the command data received from any IST. Validation includes an authorization check, command criticality checks, and schedule consistency.

7b. The EOC Scheduler performs constraint checking on all uplink data to ensure that there are no violations of spacecraft constraints.

8. The EOC Scheduler creates spacecraft loads and corresponding ground scripts for use by real-time operations. The ground script contains the ground directives necessary to uplink the spacecraft loads for each spacecraft, dump the spacecraft recorder, and process real-time housekeeping data.
9. The Off-Line Engineers review the command history in order to assess the command results.

### 3.3.3 Real-Time Scenario

This section describes a scenario that exemplifies nominal real-time operations in a multiple spacecraft environment. Inputs to this scenario include ground scripts and spacecraft and instrument loads that are produced by the Command Management service. Loads for each spacecraft and its instruments are available at the EOC for uplink approximately 24 hours in advance. The EOC ground scripts include steps to: uplink the loads; to dump the spacecraft recorders; and ground directives. Figures 3.3.3-1, FOS Real-Time Operations for U.S. EOS Spacecraft depicts the scenario described below.

The Operations Controller leads the shift operations for all spacecraft. Responsibilities include: briefings and debriefings; monitoring activity timeline; coordinating institutional interfaces (i.e. NCC, FDF, EDOS); coordinating real-time scheduling changes; approving real-time commanding; and anomaly resolution.

Concurrent operations of multiple spacecraft are handled by multiple Command Activity Controller/Spacecraft Evaluator and Instrument Evaluator teams. Each team performs steps 1 through 7 in the subsequent scenario to provide the real-time operations for their designated spacecraft and instruments. The EOC provides each spacecraft simultaneous Telemetry and Command services. A given team need not be dedicated to a single spacecraft, but can instead support any given spacecraft for a period of time (e.g. a contact or a shift).

During real-time operations, the EOC ingests and processes as spacecraft housekeeping telemetry, instrument housekeeping telemetry, and instrument engineering telemetry. Engineering telemetry data in a broad sense refers to the telemetered data available relating to the health, safety, environment, or status of the spacecraft and instruments. The spacecraft housekeeping telemetry refers to the subset of telemetered engineering data required for performing spacecraft operations. Similarly, the instrument housekeeping telemetry refers to the subset of telemetered engineering data required for performing instrument operations. Finally, the instrument engineering telemetry refers to the subset of telemetered engineering data required for performing instrument operations and science processing.

For each type of telemetry, the EOC ingests both real-time and spacecraft recorded data. Real-time data refers to data that is acquired and transmitted immediately to the ground. Delays in real-time data are limited to the actual time of transmission. Spacecraft recorded data refers to data that has been stored on-board the spacecraft for delayed transmission to the ground.

#### 3.3.3.1 Pre-Contact

1a. The Command Activity Controller (for a given spacecraft and its instruments) issues a directive that initiates the EOC ground script for that spacecraft and the current day. The EOC ground script consists of time stamped directives for the EOC to process the current day's contact periods. The Command service performs an authorization check prior to activating the ground script. The ground script for a given spacecraft may only be initiated by the Command Activity Controller with command authority for that spacecraft (i.e. there is a single-point of command per spacecraft).

2a. Once authorization is verified, the ground script is activated. The EOC executes the directives in the EOC ground script as indicated by the time stamp associated with each directive. The EOC ground script execution, for a given spacecraft, and its instruments is controlled by the Command Activity Controller and monitored by the Instrument Evaluator. The EOC executes ground scripts for multiple spacecraft concurrently and independently.

3. Prior to the scheduled contact for a designated spacecraft, the EOC ground script for that spacecraft performs the necessary setup to ingest and process the real-time spacecraft and instrument housekeeping telemetry. This setup may include changes to limit sets, and ground equipment checkout. The Operations Controller is responsible for verifying the pre-contact ground configuration.

#### 3.3.3.2 Contact

4a. At a scheduled contact for a given spacecraft, the EOC automatically ingests and processes the real-time spacecraft and instrument housekeeping telemetry and instrument engineering telemetry. Subsets of the processed housekeeping telemetry may be forwarded to the FDF. The EOC ingests and processes real-time telemetry for multiple spacecraft and their instruments concurrently and independently.

4b. The Spacecraft Evaluator for a given spacecraft monitors telemetry displays providing information on the health and safety of that spacecraft and its subsystems. The

Spacecraft Evaluator is notified of critical events such as missing data, bad quality, and limits violations.

4c. The Instrument Evaluator at the EOC and the PI/TL at the IST monitors telemetry displays providing information on the health and safety of the instruments. The Instrument Evaluator is notified of critical events such as missing data, bad quality, and limits violations.

5a. During the contact for a given spacecraft, loads may be uplinked to that spacecraft either via the automated ground script or via a real-time directive entered by the Command Activity Controller. Prior to a load being uplinked via the real-time directive an authorization check is performed by the Command service. The Command service uplinks the load via EDOS and performs command verification. The EOC uplinks loads for multiple spacecraft concurrently and independently.

5b. The Spacecraft Evaluator and Command Activity Controller for a given spacecraft are notified of the uplink status and verify the execution of spacecraft commands.

5c. The Instrument Evaluator at the EOC and the PI/TL at the IST are notified of the uplink status and the verification status of instrument commands. For AM-1, the loads are verified by examining a Cyclic Redundancy Check (CRC) status, which is included in the housekeeping telemetry. Real-time commands are verified by examining the command verification status in the housekeeping telemetry.

6a. Real-time commanding may be initiated by the Command Activity Controller via a directive or the ground script. The Command service performs the authorization check, validates the command, and uplinks the command via EDOS. The EOC uplinks real-time commands to multiple spacecraft concurrently and independently.

6b. The Instrument Evaluator at the EOC and the PI/TL at the ISTs may request that a real-time command be uplinked during the contact. The Command Activity Controller may grant or deny this real-time command request. (Note: All command input from an IST, exclusive of instrument micro-processor loads, are in mnemonic form. Depending on the criticality of the command, concurrence from the EOC Command Activity Controller may be required prior to uplink.)

#### 3.3.3.4 Post-Contact

7. Following the contact for a given spacecraft, the ground script executes directives to enable the Telemetry service to ingest and process spacecraft recorded spacecraft and instrument housekeeping telemetry from EDOS. The spacecraft recorded telemetry is temporarily archived for local use by the Spacecraft Analysis service and permanently archived at the GSFC DAAC. The Spacecraft Evaluator verifies the successful completion of this operation. The EOC ingests and processes spacecraft recorded telemetry from EDOS for multiple spacecraft concurrently and independently.

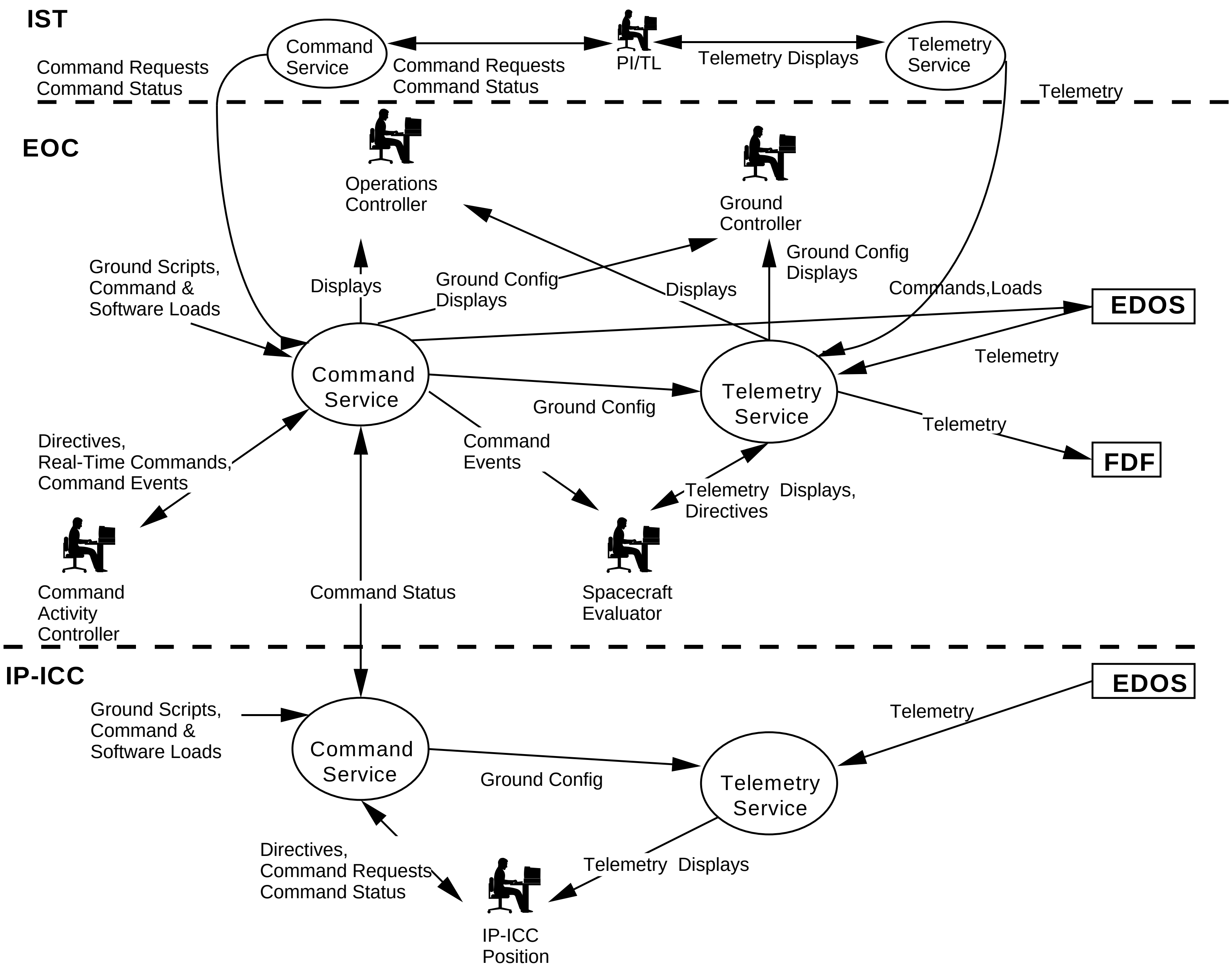



*Figure 3.3.3-1. Real-Time Operations for U.S. EOS Spacecraft*

### 3.3.4 Spacecraft Analysis Scenario

The Spacecraft Analysis service provides the FOT Spacecraft Evaluators, Instrument Evaluators, and Off-Line Engineers a set of tools to analyze spacecraft and instrument anomalies and deviations from expected performance standards. In particular, the Off-Line Engineers routinely analyze housekeeping telemetry trend data on the spacecraft subsystems to identify performance fluctuation issues (e.g., battery performance). Specific tools aimed at evaluating the functions, resources, and performance of spacecraft subsystems (e.g., Propulsion subsystem) are also routinely exercised by the Spacecraft Evaluator and the Off-Line Engineer.

After identifying a problem and its corrective action, the Spacecraft Evaluator and/or Off-Line Engineer follows approved procedures. If the anomaly is not time critical, the Spacecraft Evaluator and Off-Line Engineer works with the Mission Planner/Scheduling Supervisor and Scheduler to ensure that the corrective action plan is incorporated into a detailed activity schedule. If the corrective action is time critical, the Spacecraft Evaluator and Off-Line Engineer works with the Command Activity Controller to ensure that the corrective action plan is incorporated into the next available real-time contact period. In both cases, the corresponding commands are ultimately built, uplinked to the spacecraft, and verified.

The Spacecraft Evaluator and Off-Line Engineer also are provided with the capability to analyze real-time spacecraft housekeeping telemetry, spacecraft recorder housekeeping telemetry, and previously archived housekeeping telemetry. The selection of the telemetry to be analyzed, the time period over which the analysis is to occur, and the type of analysis to be performed (e.g., plot parameter(s) vs. time) are defined by the Spacecraft Evaluator and Off-Line Engineer.

Another function available to the Spacecraft Evaluator and Off-Line Engineers is to compare the Spacecraft Controls Computer (SCC) memory against the master ground image of the SCC memory. Nominally, the spacecraft loads are verified via the CRC check by the Command Activity Controller. However, in the case of an anomaly, the Spacecraft Evaluator and Off-Line Engineer can compare the SCC memory against the master ground image of the SCC memory.

The following scenario, depicted in Figure 3.3.4-1, demonstrates, in principal, how a Off-Line Engineer would detect, report, and resolve a spacecraft Power subsystem anomaly.

1. The Spacecraft Evaluator monitors the real-time housekeeping data for the Power subsystem. While monitoring the data, a yellow (warning) limit violation occurs that specifies that a threshold value has been crossed.

2. The Spacecraft Evaluator invokes a tool to provide in-depth analysis of the Power subsystem. This tool compares current values versus expected values, as well as analyzing trending data associated with the Power subsystem.

   The data analyzed in this scenario is real-time data, archived back-orbit housekeeping telemetry, and trend data. The Spacecraft Evaluator specifies the set of Power subsystem telemetry parameters to analyze. The Spacecraft Evaluator compares the results of a report of current value versus expected value. The plot indicates how a value has slowly degraded in the past several weeks.

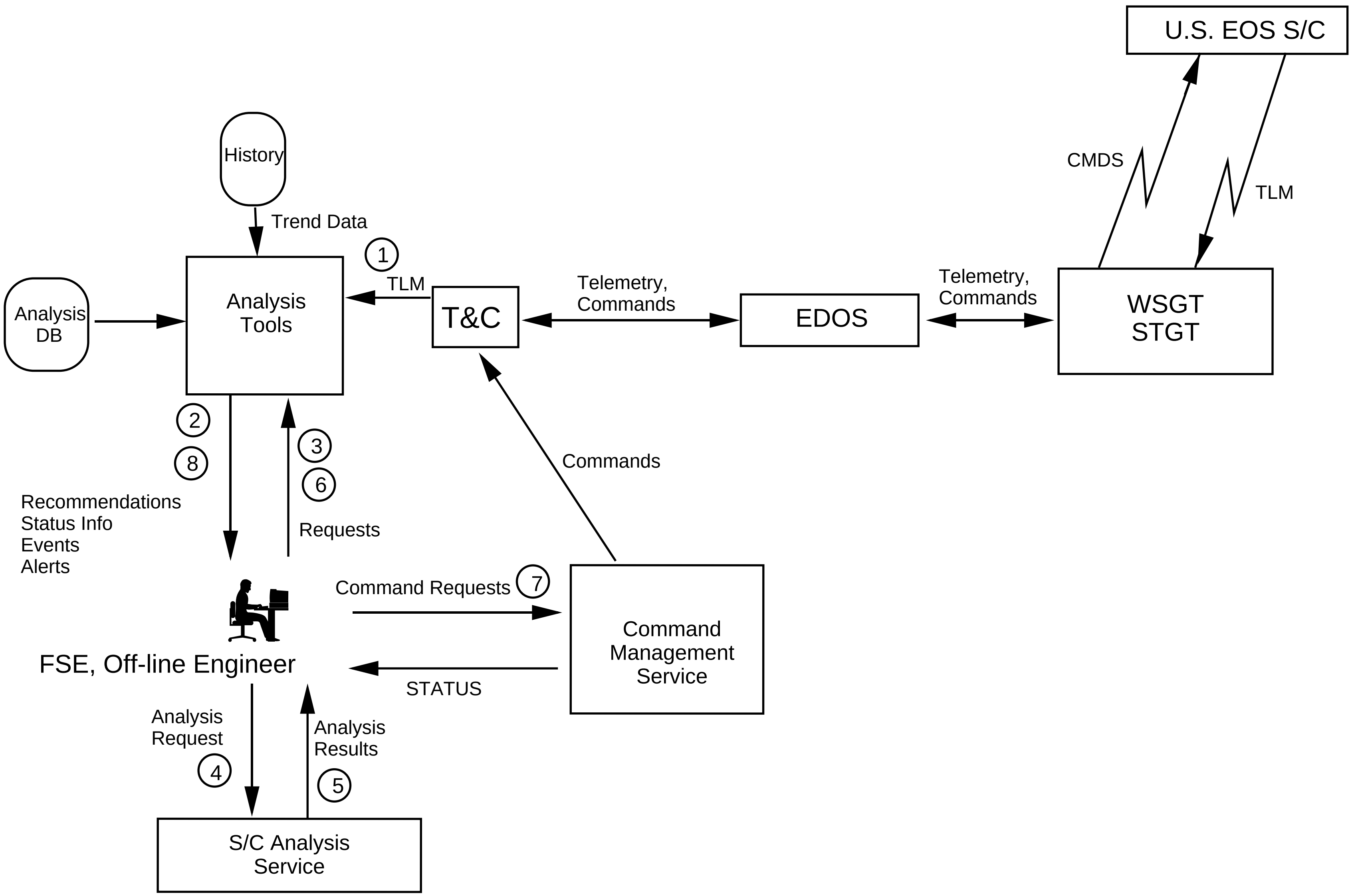



***Figure 3.3.4-1. Spacecraft Analysis***

3. From the results of the analysis, the Spacecraft Evaluator and Off-Line Engineer identify a corrective action plan that should be pursued. They follow pre-approved procedures to get the corrective action plan approved.

4a. If the corrective action plan is not time critical, the Off-Line Engineer consults with the Scheduler to identify when the approved corrective activity can be incorporated into a detailed activity schedule.

4b. The Scheduler adds the activity to the applicable detailed activity schedule.

4c. The Off-Line Engineer reviews this schedule, and gives his approval.

5. If the corrective action plan is time critical, the Off-Line Engineer consults with the Command Activity Controller to identify when the approved corrective activity can be incorporated into a real-time contact.

6. The associated commands are uplinked to the spacecraft and verified. Subsequently, the corrective action commands are executed on-board the spacecraft.

7. The Spacecraft Evaluator reviews the real-time telemetry parameter(s) associated with the Power subsystem degradation anomaly, and confirms that the parameter(s) is now within the yellow limits range.

8. The Spacecraft Evaluator plots the expected resource value versus the actual value to re-confirm that the corrective action has been successful. Final validation is confirmed by the Off-Line Engineer in conjunction with the Spacecraft Evaluator.

## 3.4 Flight Ops Concept

Appendix A is a subset of and is directly based on, and is a descendent of, the Earth Observing System Data and Information System (EOSDIS) Flight Operations Segment (FOS) Operations Concept, Revision 4, dated March 1993 prepared for Goddard Space Flight Center by Computer Sciences Corporation under Contract NAS 5-31500.

### 3.4.1 Overview

This appendix presents a more detailed operations concept for the flight operations concepts than Section 3.0, which presented operational scenarios for flight operations. The flight operations is responsible for the operation of the EOS flight elements, including the U.S. spacecraft and instruments. The concepts for the operational activities of the flight operations come from analyses of EOSDIS requirements and interfaces and of the needs of the scientific community.

This appendix covers the major characteristics of flight operations, the operational components within EOSDIS, the interaction of the personnel with the flight operations computer systems, the facilities concepts, and the assumptions on which the operations concepts are based. It describes in detail the basic flight operations activities, including planning and scheduling activities and observations, commanding the instruments and spacecraft, and monitoring them using the resulting telemetry. In addition, it presents, in general, the concepts for spacecraft and instrument analysis, data management, flight operations support, integration and test, and launch and early orbit support. This appendix also describes the basic activities individually for specific EOS spacecraft and instruments.

## 3.4.2 Overview of Flight Operations

EOS flight operations are influenced by EOS program characteristics. Two interconnected elements constitute the flight operations: the EOC and the ISTs. A variety of personnel participate in the functions of these flight operations elements and use their interactive computerized systems in the facilities that house the elements. The flight operations elements interact with external entities via well-defined interfaces. The flight operations concepts presented in this document are based on a set of assumptions about EOS and about the NASA facilities that will support it.

### 3.4.2.1 Characteristics of EOS Flight Operations

The EOS program has several special characteristics that influence the concepts and design of its flight operations. The dominant factors include distributed instrument operations, the diversity of the spacecraft series and science instruments, the evolution of the program and thus of the flight operations, and the spacecraft life cycle and multiple spacecraft operations.

**Distributed Instrument Operations.**

Each instrument and its operation are the responsibility of its PI or TL. (PIs have responsibility for their own instruments; TLs act for the institutions that provide facility instruments.) The flight operations is geographically distributed to allow PIs/TLs and instrument engineering teams to exercise this responsibility from their home facilities. An IST allows these personnel to access any flight operations-related information associated with their instrument’s operation and to perform any instrument operations function except direct commanding. Using ISTs, the PIs/TLs or instrument engineering teams can review plans, define schedules, check command loads, monitor instrument housekeeping and engineering data, and evaluate quick-look science data. During special operations, such as anomaly investigations or initial instrument activation, the PI/TL or instrument engineering team may command their instrument via requests to the Command Activity Controller at the EOC while the ground is in contact with the spacecraft.

The EOC performs both routine and round-the-clock operations for most instruments. In addition, one or more EOS instruments is operated by control centers external to the EOC (e.g., the Japanese center for ASTER). Each external control center is responsible for its instrument operation and submits schedule and command information to the EOC, which integrates it with the activities of the other instruments and the spacecraft.

The instrument control functions are also distributed. The allocation of instrument control functions between the EOC and IST is determined uniquely for each instrument.

The international distribution of EOS operations presents challenges due to differences in language and time zone.

**Diversity of Spacecraft and Instruments.** Flight operations must support a wide range of instruments and spacecraft. Diverse science needs mandate a variety of instruments, and launch vehicle availability and contractual considerations lead to a diverse set of spacecraft.

Some instruments are operationally very simple: they operate continuously, routinely, and autonomously, requiring no scheduling or routine commanding (e.g., MOPITT on AM-1). A few others are more operationally complex. Such instruments require more sophisticated planning and scheduling tools. The flight operations must combine the activities of the full spectrum of instruments into an effective set of activities for each spacecraft without unduly burdening the operations of the simpler instruments or unnecessarily constraining those of the more complex instruments.

The basic operations approach balances the need for preplanned data acquisition with the need for timely response to late changes (note: late changes includes TOOs for IP-ICC instruments such as ASTER). One major goal of the EOS mission is to provide a long-term, complete set of science information to support both modeling and the detection of subtle, long-term changes. This drives the mission to be extensively preplanned. On the other hand, goals involving the observation of short-term phenomena such as volcanic eruptions and natural disasters require quick responses from the flight operations. The flight operations must combine effectively the execution of preplanned EOS activities with the need for quick responses.

The spacecraft are diverse as well. Differences among them are driven by factors involving procurement, technology growth, and/or instrument accommodation. Furthermore, EOS spacecraft may even vary within a series. The flight operations must accommodate the variety in the EOS spacecraft and must provide similar functions and services for all of them.

**Spacecraft life cycle and multiple spacecraft operations.**

The flight operations must cover the life cycle of the spacecraft and instruments. Operations begin before launch as the FOT participates in instrument and spacecraft ground tests. Tests occur at the spacecraft developer's facility and continue shortly before launch at the Vandenberg Air Force Base launch site. The flight operations monitors the launch. Once on orbit, the instruments and spacecraft undergo checkout and make the transition to normal operations. Anomalies or late changes occasionally interrupt normal operations.

At any given time, as many as seven spacecraft may exist in various operational phases at the EOC. The flight operations must be able to operate each spacecraft without interfering with the operations of others. Some of the operations personnel (e.g., Schedulers) may have to support more than one spacecraft operations team; others of the operations staff may have to be dedicated to spacecraft of a particular series.

**Evolution.** During its 20-year lifetime, the EOS mission will see increasingly complex spacecraft and instruments, improved technology in ground and flight systems, and changing concepts of spacecraft operations. The flight operations must evolve to accommodate these changes. Flight operations evolution may require modifications to flight operations functions and redistribution of functions among the EOC and ISTs.

#### 3.4.2.2 Flight Operations Elements

The flight operations is responsible for EOS mission operations, including the planning, scheduling, commanding, and monitoring of spacecraft and instruments. The flight operations comprises the EOC, and the ISTs for each instrument. Collectively, these components work together to fulfill these responsibilities. Control for most EOS instruments resides at the EOC, collocated with the spacecraft control function.

**EOS Operations Center (EOC).** The EOC is responsible for the high-level monitoring and control of EOS mission operations and for the operation of the spacecraft and instruments. Working with PIs/TLs, the EOC plans and schedules spacecraft operations. It generates commands and integrates them with any instrument commands received from the PIs/TLs via their ISTs. The EOC maintains health and safety for the spacecraft and instruments monitors their performance, and produces periodic reports on their operations. It also analyzes housekeeping, engineering, and instrument quick-look data to support operations and to support spacecraft and instrument sustaining engineering.

**Instrument Support Toolkits (ISTs).** ISTs are software toolkits that run on PI/TL-provided workstations outside the EOC. An IST provides the interface that connects the instrument PI/TL and/or instrument team with the functions and operations personnel at the EOC (Figure 3.4.2.2-1). One or more ISTs per instrument enable the remote instrument experts to participate in the planning, scheduling, commanding, and monitoring of their instrument. If a team has multiple ISTs, coordination is required to ensure that their interactions with the EOC do not conflict with each other. The procedures for such coordination are established during mission planning.

ISTs provide for the exchange of data between the EOC and other instrument support systems at the PI/TL or instrument team locations (e.g., for transfer of instrument microprocessor loads and dumps). Different authorized individuals may use an IST for different functions in support of instrument operations (e.g., some IST users may support planning and scheduling; others, anomaly resolution). Before launch, the PI/TL and the EOSDIS project negotiate the allocation of instrument operations functions to the IST or the EOC. Instruments for which some operations are allocated to the EOC may not need all of the IST services.

ISTs run on a wide range of computer workstations that conform to industry standards. The PI/TL is responsible for ensuring that the hardware that hosts the IST meets the applicable standards. It addition, the PI/TL is responsible for integrating the toolkit with the hardware and other PI/TL applications.

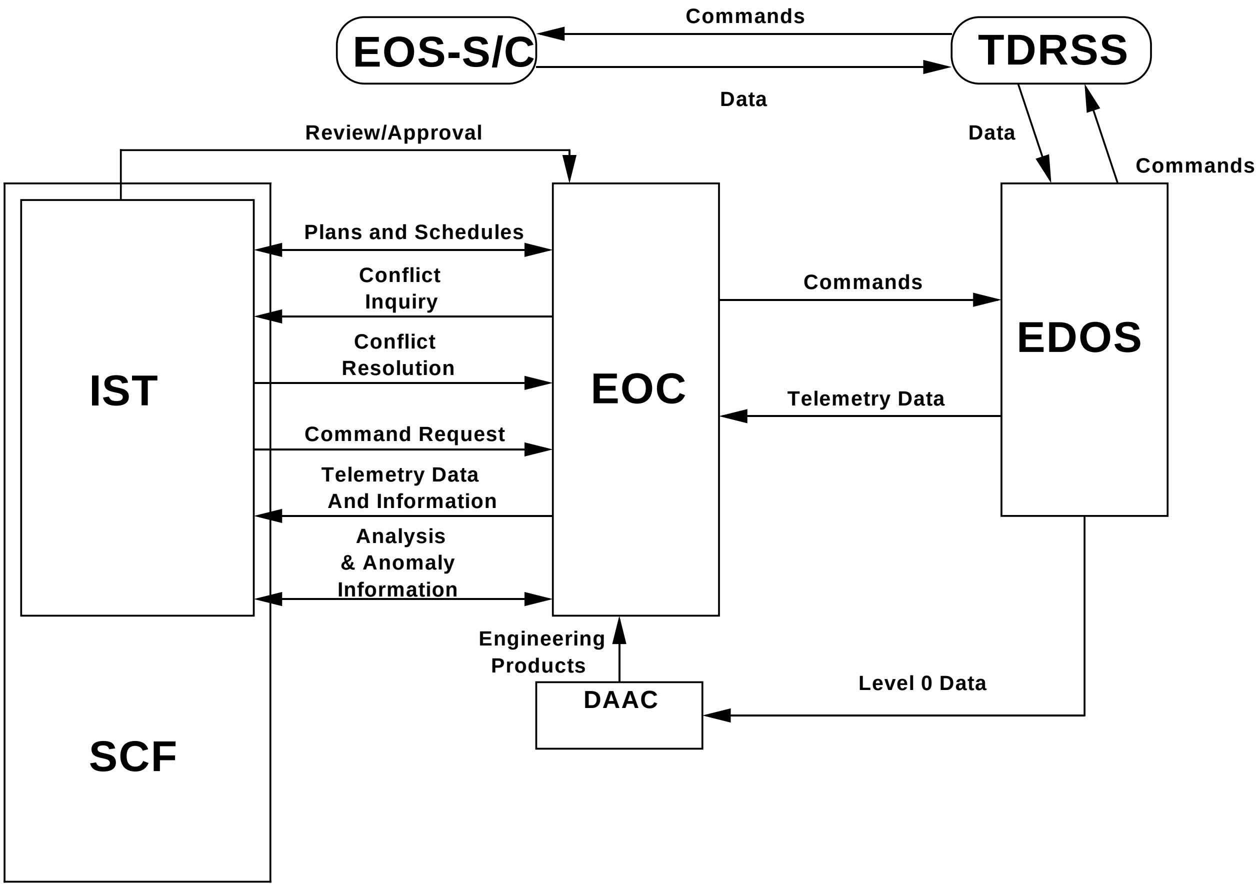



***Figure 3.4.2.2-1. IST User Perspective***

### 3.4.2.3 Human Interaction

This operations concept describes an allocation of EOS operational responsibilities and activities to the EOC and the PIs/TLs and associated instrument personnel who use ISTs. However, it does not presuppose that functions within an FOS element are allocated in any specific way to the components of that element (e.g., personnel, hardware, software). Differences between the EOC and the ISTs necessitate slightly different terminology concerning the involvement of personnel in EOS flight operations.

The EOC is a complete center; it includes personnel as an integral part, along with the hardware, software, facilities, operational procedures, documentation, training, and everything else that constitutes a computerized system. Therefore, a flight operations activity that this document described as being performed by the EOC could in fact be performed by any combination of personnel, hardware, and software. In contrast, ISTs are toolkits that support the PI/TL and associated instrument operations staff, but do not include any personnel within them. For this reason, an IST cannot perform EOS instrument operations autonomously. For EOS operations that are supported by ISTs, this document describes them as being performed by the PIs/TLs using ISTs.

However, all flight operations personnel, in all centers and at all terminals, have access to virtually all flight operations functions and computational capabilities (except, for example, that ISTs do not enable their users to perform direct real-time commanding) and interact with the flight operations hardware and software in virtually identical ways to perform those functions. The computer systems of the various flight operations elements provide common mechanisms for interacting with the functions and for directing and controlling the spacecraft and instruments (as appropriate). These computer systems have essentially identical human-computer interfaces (HCIs).

**Human-Computer Interfaces.** Human beings play a significant role in EOS flight operations. They participate in scheduling, commanding, and monitoring activities, and they exchange an extensive amount of information with and through their computer systems. To perform their activities effectively, flight operations personnel will need:

- Mechanisms explicitly for directing the activities of the spacecraft and instruments
- Timely status information on the spacecraft, instruments, and flight operations activities
- Access to all flight operations-related spacecraft and ground system data (real-time and archived data)
- Interaction styles and mechanisms to support different tasks and varying levels of human knowledge and skills
- The ability to conduct multiple activities concurrently
- Facilities for communicating with other personnel involved in EOS flight operations
- On-line help
- Special support for remote operations

Interactive HCIs designed to incorporate human factors principles and guidelines will provide the high level of system usability needed for a mission as complex as EOS.

A high-level control language provides the operations personnel with a mechanism for directing (via their computer systems) the activities of the spacecraft and instruments. This language also supports the personnel in activating and directing the support functions of their computer systems. It enables them to “program” their interaction by defining and executing procedures that include (for example) expression evaluation, logical decision making, intraprocedure branching, procedure nesting, and initiation of other procedures.

The flight operations HCIs support the transmission to operations personnel of up-to-date information on the status of the spacecraft and instruments and on the activities currently being performed by the flight operations. For example, operations personnel may want to identify the status of a specific flight operations activity. Also, they may receive alert notification about commands or combinations of commands that have the potential to endanger the spacecraft or instruments.

Through the flight operations HCIs, the operations personnel have access to all spacecraft and ground system data with which the EOC/IST functions are concerned. They have efficient access to the various data bases (e.g., spacecraft and instrument data base, and operations logs. The personnel are able to define new arrangements of information (format and content) and to direct the output of these arrangements to screens, printers, and files. They may direct on-screen information to be displayed statically (displayed once) or dynamically (displayed once and updated at regular intervals).

Flight operations involve many types of people performing diverse tasks using a wide variety of knowledge, skills, and personal preferences in interaction style. Flight operations HCIs provide a variety of styles and techniques for the exchange of data and control information between human and computer. For example, they support more than one type of input device, perhaps having both a keyboard and a pointing device (e.g., a mouse). Also, they support parallel styles of control mechanism, such as “point and click” graphic techniques and “hot keys” for more rapid activation of functions. All HCI features have the same design throughout the flight operations, so that users activate and control the functions similarly through the EOC and ISTs. Users are able to customize some HCI features unrelated to the activation and control mechanisms.

Flight operations personnel are able to conduct multiple activities concurrently. The flight operations HCIs enable them to initiate one computer-based function while others are active and provide mechanisms (windowing techniques, for example) for navigating around the active functions and for identifying which function has the current focus.

The various personnel involved in EOS flight operations need to communicate with one another to resolve questions and make decisions about flight operations. Flight operations personnel must have facilities for non-real-time communication (e.g., electronic mail).

The HCIs also support online help for the flight operations functions and for the use of the computer systems in performing those functions. Through the HCIs, operations personnel have access to tutorial and quick-reference information that is context sensitive (related to the person’s current activity).

The ISTs support the PIs/TLs and their personnel in operating their instruments via the EOC. The ISTs provide the PIs/TLs with access to the EOC functions and support the transmission of instrument operations data to the EOC (as appropriate) and the reception of instrument operations data from the EOC. Because the workstations that host the ISTs support the PIs/TLs in performing non-IST work as well, each IST is capable of alerting the PI/TL to events as notified by the EOC (e.g., instrument anomalies found during instrument monitoring), regardless of the activity for which the PI/TL is using the workstation.

#### 3.4.2.4 Facilities Concepts

A set of physical facilities houses the flight operations elements. These facilities provide physical security and backup services, and they support simultaneous operations.

**Physical Security.** Automated personnel access control systems, such as keycard systems, protect the EOC from unauthorized access. Personnel without keycards require escorts within the facilities. Visitors may view operations from glass-walled hallways or viewing areas.

**Backup Services.** The EOC is internally redundant and can perform all essential operations functions in the event of a single failure. Uninterruptible power supply systems allow operations to continue through momentary outages and to come to an orderly shutdown in the event of an extended outage.

**Simultaneous Operations.** Flight operations facilities can support multiple simultaneous operations with minimal interference between activities. Potential operations include on-orbit operations, testing, development, sustaining engineering, maintenance, and staff training for each spacecraft, including the double workload needed for changeout from an on-orbit spacecraft to its replacement. The flight operations team operates each series of spacecraft independently. Even the scheduling of TDRSS contacts is done independently: A separate TDRSS contact request is prepared for each contact for each EOS spacecraft in orbit.

The flight operations facilities undergo configuration management to ensure both the stability of the operating environment (e.g., operational data base, hardware, software) and a smooth transition from each configuration to its successor (as described in Section 3.4.8.2). If a new configuration differs considerably from its predecessor, changeover should include the use of both configurations in parallel for a short time to facilitate the change and boost the confidence of both users and management in the new configuration.

Maintenance, development, sustaining engineering, and testing function on systems other than the operational systems to the maximum extent possible. For the most part, use of the operations systems for these activities is limited to verifying that the final test conducted on the development systems accurately duplicated the operational environment.

The EOC operations areas can be reconfigured to support varying levels of operations staff over the life of the spacecraft. This area can support the additional personnel needed for launch, on-orbit checkout, and anomaly investigation.

#### 3.4.2.5 Assumptions

The flight operations concepts presented in this document depend on a number of assumptions about EOS and about the NASA facilities (e.g., SN, FDF) that support it.

The EOS spacecraft and instruments are designed with the goal to minimize contention for resources among instruments or between instruments and spacecraft subsystems. Spacecraft resources are sufficient for the non-complex instruments in their routine operating modes. Over time, however, some spacecraft subsystems, for example the electrical power subsystem, may degrade in performance resulting in a resource-constrained spacecraft environment. When such a situation arises, specific scheduling is required for a feasible, effective, and productive operation.

NCC scheduling operates in two modes, forecast and active. Forecast scheduling occurs weekly, and the resulting schedule spans exactly 1 week. The forecast scheduling period lasts 2 weeks and ends 7 days before the target week. During the forecast scheduling period, the NCC accepts requests and resolves conflicts, if any, between SN users. About 7 days before the target week, the NCC issues the active schedule and any rejected requests (where it could not resolve conflicts). Active scheduling extends from when the schedule is published to the end of the target week and involves making changes (additions, deletions, and modifications) to the active schedule. The EOC may request updates to the active schedule up to 10 minutes before the requested start time. The NCC rejects these change requests if they conflict with a scheduled activity unless the EOC declares a spacecraft emergency.

The FDF can provide predicted orbit data 21 days in advance of the target week.

An EOS spacecraft nominally has up to 20 minutes of TDRS contact per orbit in one or two contacts. These contacts are used for both Ku-band recorder dumps and S-band housekeeping and command data. (Note: nominally 20 minutes in based on AM-1 spacecraft; other EOS spacecraft contacts per orbit may vary from this value.)

The EOS spacecraft can store data acquired by the instruments and spacecraft subsystems between TDRSS contacts. The storage capacity is large enough that even if a scheduled contact is lost all data acquired between the last contact and the next contact can be accommodated.

Some of the spacecraft terminology used in Sections 3.4.1 through 3.4.9 of this document is taken from the EOS-AM-1 spacecraft design. These terms are intended to apply to the equivalent functional elements of all EOS spacecraft.

## 3.4.3 Planning and Scheduling

### 3.4.3.1 Introduction

Planning and scheduling has the objective of producing a detailed schedule for the activities of the spacecraft and its instruments. Three steps are necessary for developing this schedule: long-term mission planning, initial scheduling, and final scheduling. Long-term mission planning establishes the mission objectives and overall science operations plans and is largely performed outside the FOS. The flight operations team contributes to long-term mission planning by producing a long-term spacecraft operations plan that is consistent with the overall science operations plans. This section focuses on the flight operations activities during the initial and final scheduling phases.

The complexity and performance of scheduling are largely determined by three factors: degree of resource contention, coordination requirements, and schedule stability. These factors are, in turn, determined by the operational characteristics and complexity of the different types of instruments. An instrument is defined as “complex” if it is capable of non-contiguous data acquisition with variable pointing; otherwise, it is defined as “non-complex.” Non-complex instruments have activities that are routine and repetitive. Such a well-defined and stable set of activities for a non-complex instrument is termed its baseline activity profile. An actual activity profile for such an instrument deviates from its baseline to accommodate such activities as sporadic calibrations or occasional collection modifications. In contrast, the activity profile of a complex instrument is highly variable. As a result, no baseline activity profile can be defined for such an instrument, and its activities are a significant driver in scheduling.

An important objective in the design of the EOS spacecraft and instruments is the avoidance of resource contention among instruments and between instruments and spacecraft subsystems. Spacecraft resources are sufficient for the non-complex instruments in their routine operating modes. Resources available to the complex instrument (if there is one) are those that are left unused by the non-complex instruments. This designed-in resource allocation must be managed for the variable activities of the complex instrument. Therefore, the task of managing resources in flight operations scheduling is primarily a communications management effort involving the complex instrument, the spacecraft recorders, and the SN. Over time, however, some spacecraft subsystems, (e.g., the Electrical Power subsystem) may degrade in performance resulting in a resource-constrained spacecraft environment.

Scheduling coordination would be complicated only between two complex instruments. Because no such situation is envisioned for the EOS mission, scheduling coordination will be fairly simple.

Schedule stability concerns two characteristics of the schedule: the length of time over which it remains fairly constant, and the extent of modification needed when it has to be modified. Schedule stability is a critical factor because the remaining flight operations activities depend on the end product of scheduling. For instance, if a substantial portion of a schedule has to be changed on a daily basis, flight operations could become very complicated (e.g., frequent interaction with the NCC, frequent command uplinking). No cause for schedule instability has yet been identified for the EOS mission.

The aforementioned considerations directly affect the implementation of flight operations scheduling. For most of the non-complex instruments, deviations of the actual activity profiles from the respective baselines are treated as exceptions and are handled primarily by people (using computerized tools) rather than by automated systems. For complex instruments, the activity profiles are variable, but generally they do not affect other instruments.

Figure 3.4.3.1-1 shows an overall timeline with sample times of planning and scheduling for a spacecraft and its instruments. This process consists of a long-term mission planning phase, an initial scheduling phase, and a final scheduling phase. Long-term mission planning for spacecraft and its instruments begins up to 5 years before the activities being planned and produces or updates the Long-Term Science Plan (LTSP), Long-Term Instrument Plans (LTIPs) and the long-term spacecraft operations plan. Initial scheduling, whose primary objective is to secure the SN resources for mission operations for the target week, begins about 3 weeks before the target week and produces a preliminary resource schedule. Final scheduling, which begins after the preliminary resource schedule is generated, produces a detailed activity schedule for the spacecraft and its instruments. This schedule forms a basis for commanding the spacecraft and its instruments.

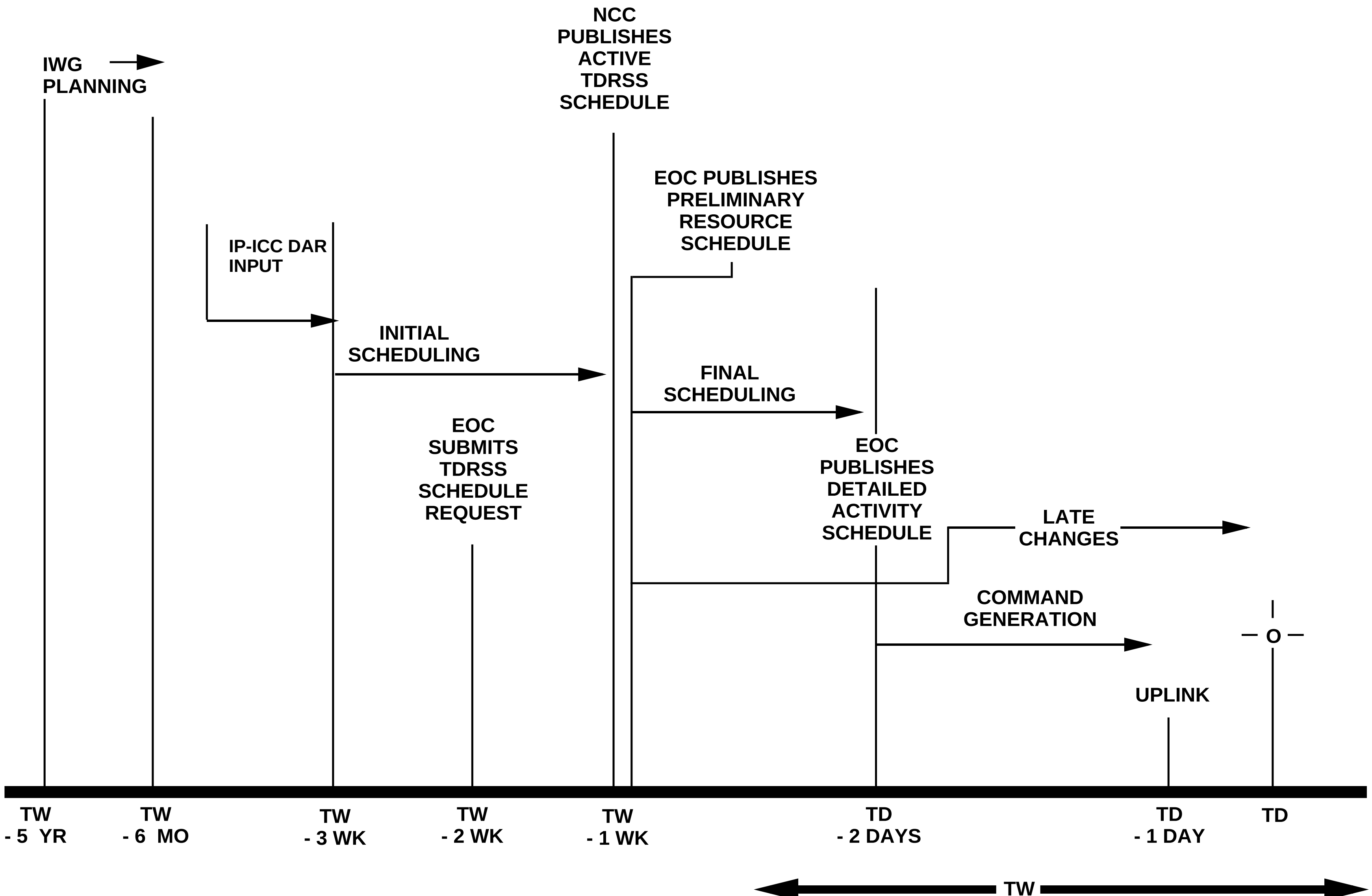
The baseline activity profiles for the non-complex instruments resides in the EOC. To conduct initial scheduling, the EOC needs for each non-complex instrument only lists of resource deviations from the baselines to generate resource profiles as required for developing a preliminary resource schedule. For final scheduling, the EOC needs for each non-complex instrument only a list of activity deviations from the baseline to generate an instrument activity list as required for developing a detailed activity schedule. In contrast, the IP-ICC complex instruments have resource profiles and an instrument activity list that are utilized by the EOC for integration into a preliminary resource schedule and a detailed activity schedule, respectively. For each instrument and spacecraft subsystem, specified activity information includes resource information and vice versa, so that resources can be managed along activity lines. In addition, the

EOC can generate resource profiles by receiving activity deviations (during initial scheduling), because the specified activity information also includes resource information.

#### 3.4.3.2 Long-Term Mission Planning

Long-term mission planning begins outside EOSDIS. The project scientist produces, with IWG assistance, a LTSP for the spacecraft and its instrument complement. The PIs/TLs work with the project scientist to produce LTIPs for their respective instruments. The flight operations team uses these long-term plans to develop a long-term spacecraft operations plan. During the flight operations scheduling process, scheduling metrics are generated in relation to the long term plans. This information is collected by the EOC for reporting to the project scientist.

The IWG defines policy, guidelines, and overall science objectives for U.S. spacecraft. The IWG has representatives from each of the instruments on the spacecraft--usually PIs, TLs, and/or TMs. The IWG meets regularly, at least every 6 months (usually every three months). The project scientist and the Science Executive Committee of the IWG generate the LTSP with IWG approval. The LTSP presents science objectives for the spacecraft and its instruments, establishes science mission priorities to be used in later scheduling, and recommends approaches for satisfying scientific objectives. The LTSP also defines special events and specifies requirements for coordination between instruments. Through the Project Scientist, the IWG receives information on the current spacecraft health to aid in LTSP development.




Note: TD=Target Day, TW=Target Week.

*Figure 3.4.3.1-1. Planning and Scheduling Overview Activity Timeline*

The PI/TL has primary responsibility for the LTIP. This plan is based on the LTSP and the input of all involved investigators, including the associated interdisciplinary investigators, and is used as input to the subsequent scheduling process. The contents of LTIPs vary from instrument to instrument. A very simple instrument has a very brief LTIP. In contrast, a complex instrument may have a substantial number of guidelines for the scheduling of its operations, enabling the instrument operations team to conduct its day-to-day business without continually consulting the PI or TL. The LTIP also contains planned routine background operations for the instruments with ongoing observations or operations that are related to routine calibration or maintenance activities. In addition, it contains planned unique operations if these are known in advance, both for science investigations that require limited and unique observations and for operations related to special calibration activities. Any details known about observations that are coordinated with other instruments are included in the LTIP. For any non-complex instrument, the corresponding LTIP usually contains sufficient information for deriving a baseline activity profile.

The EOC has the responsibility for spacecraft planning. Some of the spacecraft subsystem activities that the EOC manages are directly related to science and to spacecraft subsystem operations; these include the power, recorder, and communications subsystems. Others support spacecraft maintenance, including battery management and orbit adjustments. The EOC formulates long-term spacecraft operations plans and keeps the IWG and PI/TLs informed of changes in spacecraft operations, including predicted frequencies in which science operations are affected for maintenance.

#### 3.4.3.3 Data Acquisition Requests

This section provides a summary of Data Acquisition Requests (DARs). In the context of the EOC, DARs have a more limited role. DARs can be produced for complex IP instruments such as ASTER. A DAR identifier is associated with activities that are sent to the EOC from the IP-ICC. The EOC retains this activity/DAR identifier relationship and reports on the status of the activity (and hence the DAR) to the IP-ICC, as applicable. The remaining discussion of DARs in this subsection is included to provide background information.

A DAR is a mechanism by which a science user requests science data from instruments that do not have exclusively repetitive data acquisition cycles. Typically, this mechanism applies to instruments with targeting capabilities. Science users submit DARs to the DAAC as part of the overall ordering capability available to the EOS science users. An on-line DAAC interface allows interactive entry of DAR fields, providing checks for lexical, syntactic, and (to a limited extent) semantic correctness. Graphical displays assist the user in generating and checking the DAR. These include geographic reference aids and spacecraft location/instrument viewing projections. The DAAC also provides instrument-specific default settings for instrument-configurable parameters and help tools to assist in instrument and instrument parameter selection.

Once the DAR has been submitted to the DAAC, the DAAC forwards it to the associated IP-ICC for processing. DARs that request coordinated observations between a complex instrument and a non-complex instrument are forwarded to the appropriate instrument schedulers and/or PI/TLs who have responsibility for coordinating the observation. If a DAR requests coordinated observations affecting multiple complex instruments, the complex instrument schedulers attempt to coordinate with each other. The complex instrument most affected by the DAR assumes responsibility for overall coordination of the observation. If it is not apparent which complex instrument should assume this responsibility, the project scientist is called upon to assign responsibility for the observation. At the IP-ICC, the DAR is examined for compliance with the long-term plans, and expanded if only minimal information is provided. Lack of clarity in the DAR may require the IP-ICC personnel to contact the requester for further additions. The IP-ICC accepts or rejects the DAR based on any guidelines and priorities established by the science team (if any), the project scientist, and the IWG. If the DAR falls outside the pre-established guidelines, it is referred to the project scientist for a decision.

Once the DAR has been accepted by the IP-ICC, notification of acceptance is provided to the DAAC, which in turn notifies the requester and provides a designated DAAC with the product request associated with the accepted DAR. Upon request, the DAAC provides the status of each active DAR to the requestor.

Some DARs received after initial scheduling may be considered as input to final scheduling. Such DARs are considered for scheduling if they are declared to be TOO DARs (Section 3.4.3.6).

#### 3.4.3.4 Initial Scheduling

Initial scheduling has the objectives of securing the required SN resources from the NCC and allocating constrained spacecraft resources (if any) to the instruments and spacecraft subsystems as needed.

On a pre-negotiated basis, the primary responsibility for the planning and scheduling of a U.S. EOS instrument is established at either the EOC or IST. Note that whenever the EOC is assigned primary responsibility for the planning and scheduling of an instrument, the EOC coordinates and consults with the PI/TL. For IP complex instruments, primary responsibility for instrument scheduling will reside at the IP-ICC.

Figure 3.4.3.4-1 shows how the FOS secures the required SN resources from the NCC. An instrument IP-ICC Scheduler generates an instrument resource profile and sends it to the Spacecraft EOC Scheduler. For non-complex instruments, the instrument EOC Scheduler and/or PI/TL generate instrument resource deviation lists and send them to the spacecraft EOC Scheduler. In the meantime, the EOC identifies the SN resources required for subsystem operations (e.g., TONS operations, orbit adjustment operations) in a spacecraft subsystem resource profile. Based on the baseline activity profiles and instrument resource deviation lists for the non-complex instruments, the EOC generates their instrument resource profiles. By combining all the instrument resource profiles with the spacecraft subsystem resource profile, the EOC estimates the recorder’s data volume profile for SN resource needs and develops a TDRSS schedule request. The EOC sends the schedule request to the NCC and negotiates with the NCC as necessary to secure the best possible SN resource allocations. Forward service needs are covered only implicitly in the above discussion because it is expected that the SN resources for uplinking command data are always sufficient whenever the SSA forward service is secured for the duration required for playing back the recorded science data.

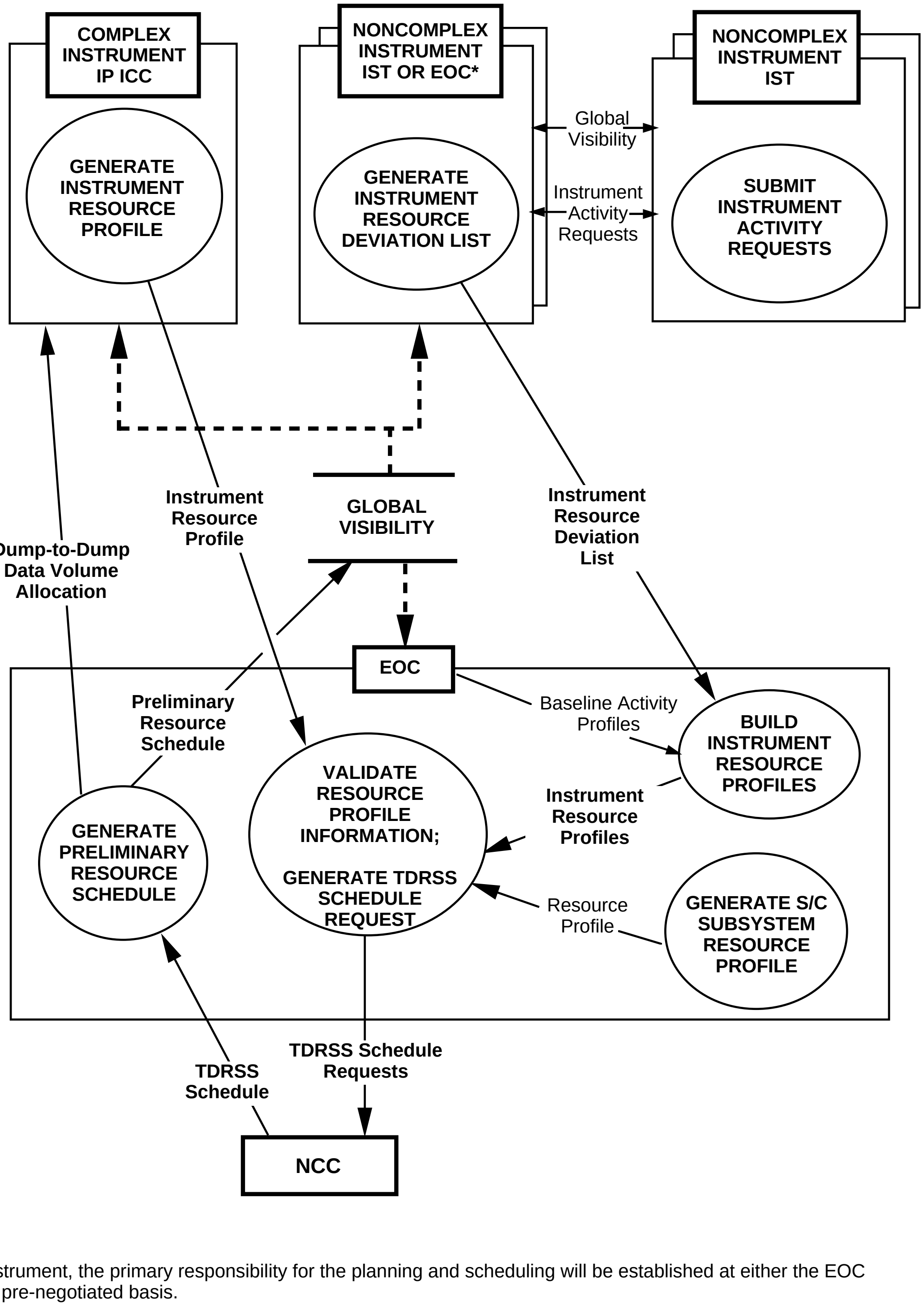



*Figure 3.4.3.4-1. Securing Space Network Resources*

The EOC allocates constrained spacecraft resources to the instruments and spacecraft subsystems. These resources may include such traditional spacecraft resources as electrical power. They may also include an environmental right to be free from external disturbances (e.g., jitter or electromagnetic interference (EMI)) and/or the privilege to produce such disturbances. The instrument EOC Scheduler and/or PI/TL express their resource needs in terms of resource deviation lists and provide them to the spacecraft EOC Scheduler. On the basis of the TDRSS schedule and the resource profiles required for the spacecraft subsystem and instrument activities, the EOC develops a preliminary resource schedule, which it makes available to all the participants.

All participants in initial scheduling--the EOC FOT and associated support personnel, the PIs/TLs at the ISTs and the IP ICC Schedulers -- have access to the globally available scheduling information. This global information includes the plans (e.g., LTSP, LTIPs, and long-term spacecraft operations plan), orbit information (e.g., scheduling aids from the FDF), a TDRSS schedule for the target week, the most current preliminary resource schedule**,** and the most current detailed activity schedule (which could be the one generated for the previous target period). The participants have access to automated tools to make full use of the information that global information sharing provides.

As previously mentioned, the complexity and performance of scheduling depend on the operational characteristics of the instruments. For initial scheduling in particular, this complexity depends on projected resource usage. For most non-complex instruments, the deviation of the data rate profile from the baseline usually falls within the margin of the SN resources associated with the baseline activity profile. Thus, initial scheduling for these instruments tends to be trivial.

Other non-complex instruments may occasionally have varying needs for SN resources. For each such instrument, the instrument EOC Scheduler and/or PI/TL identifies activity deviations from the baseline, on the basis of non-routine instrument activities to be performed separately from normal data acquisition. From these activity deviations, the instrument EOC Scheduler and/or PI/TL derives an instrument resource deviation list and sends it to the spacecraft EOC Scheduler.

For each non-complex instrument that has an instrument resource deviation list, the EOC builds an instrument resource profile by combining the resource deviation list with the corresponding resource profile associated with the baseline activity profile.

Complex IP instruments, in contrast, have resource needs that cannot be predicted much in advance of the initial scheduling phase. The IP-ICC Scheduler for such an instrument generates an approximate, yet adequate, instrument resource profile that incorporates accepted DARs, anticipated observations and instrument support activities. Once created, the instrument resource profile, containing a data rate profile along with other resource profiles, is sent to the spacecraft EOC Scheduler.

The spacecraft subsystems also have resource needs that must undergo initial scheduling. From the long-term spacecraft operations plan, the EOC identifies the activities that the subsystems must perform during the target week. Based on these activities, the EOC generates a spacecraft subsystem resource profile. The EOC uses the data rate information to identify the spacecraft subsystems' SN resource needs.

The EOC validates the resource profiles to verify that they are consistent with the spacecraft operations constraints. For example, the EOC derives the recorder's overall data rate profile and checks whether it violates the data volume operations constraints.

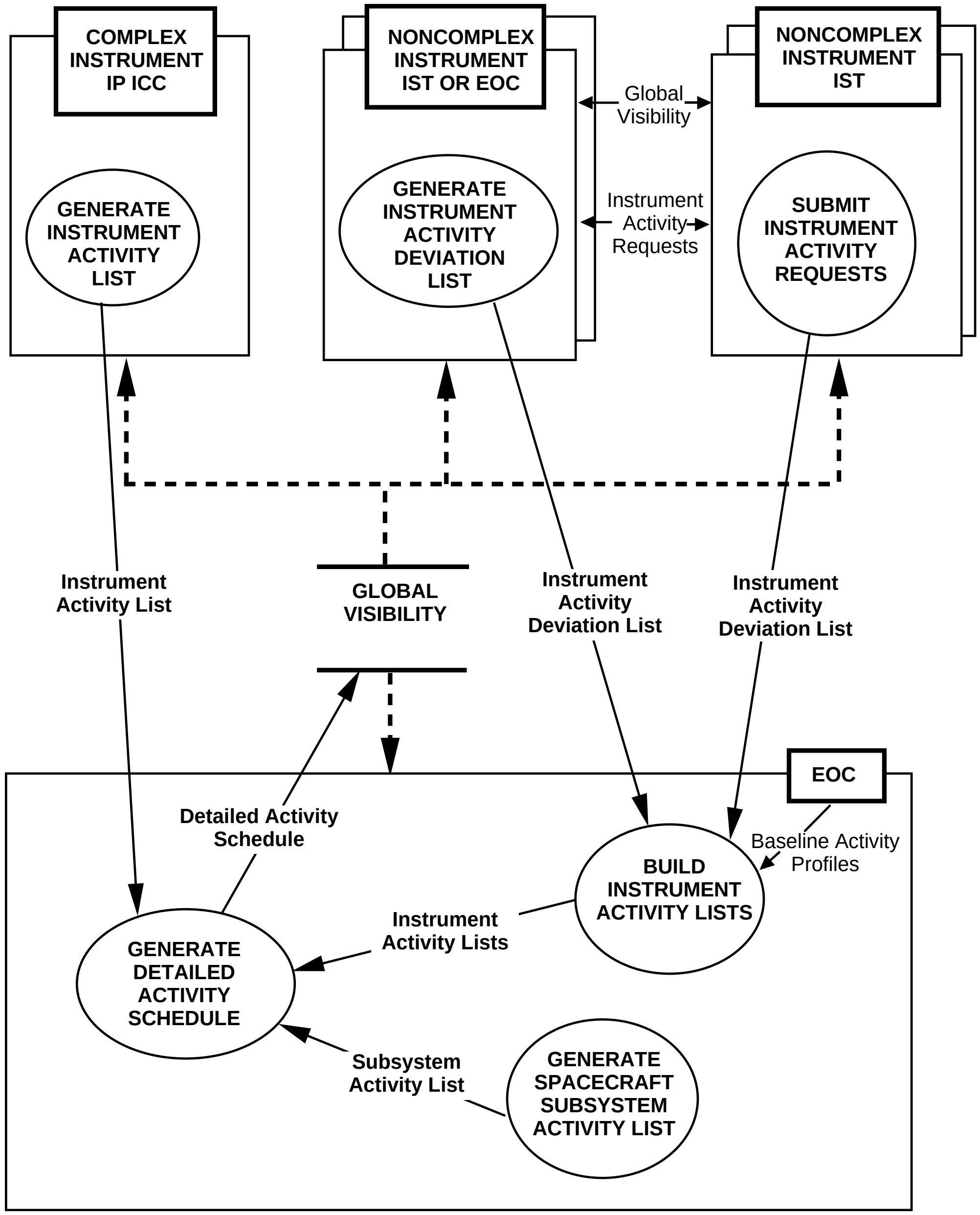
After the validation of the resource profiles, the EOC generates TDRSS schedule requests and sends them to the NCC about 2 weeks before the target week. For about a week after the submission of this TDRSS schedule request, the EOC can negotiate with the NCC for the best SN resource allocations. A week before the target week**,** the NCC provides the active TDRSS schedule to the EOC. Based on the TDRSS schedule and other resource profiles, the EOC builds a preliminary resource schedule for the target week. In particular, the EOC determines the allocation of dump-to-dump data volumes for the IP complex instrument and notifies the IP-ICC Scheduler of the allocation. The non-complex instruments normally receive the allocations that they first requested. If the complex instrument cannot accept the allocation, the EOC Scheduler may request to renegotiate with the NCC. If the NCC cannot find additional resources to accommodate the complex instrument's needs, the instrument EOC Scheduler and/or PI/TL must produce a new instrument activity list consistent with the TDRSS schedule.

#### 3.4.3.5 Final Scheduling

Final scheduling has the objective of producing for the spacecraft and its instruments a detailed activity schedule on which flight operations commanding is based. Final scheduling is based on the preliminary resource schedule and any new input that has been accepted since the preliminary resource schedule was developed. For instruments, the new input may include some late non-routine instrument activities, modifications to the preliminary resource schedule, or instrument-specific information. For spacecraft subsystems, the new input may include newly identified spacecraft subsystem activities and any changes to the preliminary resource schedule.

Figure 3.4.3.5-1 shows the roles of the EOC, ISTs and IP-ICCs in final scheduling. For an complex IP instrument the IP-ICC Scheduler and/or PI/TL develops an instrument activity list and sends it to the spacecraft EOC Scheduler. For non-complex instruments, the instrument EOC Scheduler and/or PI/TL develops the instrument activity deviation list and sends it to the EOC. The EOC then combines the activity deviation lists with the corresponding baseline activity profiles to produce instrument activity lists. The EOC develops the activity lists for the spacecraft subsystems. Based on the instrument and spacecraft subsystem activity lists from various sources, including the one from the EOC itself, the EOC generates a detailed activity schedule for the spacecraft subsystems and instruments. As in initial scheduling, all participants can take advantage of the global availability of scheduling information.

Most non-complex instruments have operations for which the EOC Scheduler can normally perform final scheduling without any input from the PI/TL. In these cases, the baseline activity profiles form the primary input to the final scheduling process. However, to accommodate non-routine instrument activities (e.g., sporadic calibration measurements), the EOC Scheduler and/or PI/TL compile instrument activity deviation lists conforming to the preliminary resource schedule and any new input received since the preliminary resource schedule was developed. The instrument EOC Scheduler and/or PI/TL provide the resulting activity deviation lists to the spacecraft EOC Scheduler.




* For each instrument, the primary responsibility for the planning and scheduling will be established at either the EOC or IST on a pre-negotiated basis.

***Figure 3.4.3.5-1 Final Scheduling***

For each non-complex instrument that has an instrument activity deviation list, the EOC builds an instrument activity list by combining the instrument activity deviation list with the baseline activity profile.

For a complex IP instrument, the IP-ICC Scheduler prepares an instrument activity list that conforms to the preliminary resource schedule and any new input that has been received since the preliminary resource schedule was developed. In addition to a detailed sequence of instrument activities for a few days, the instrument activity list contains the predicted spacecraft resources to be used and the environmental conditions expected for the instrument. The IP-ICC Scheduler must ensure that its instrument activity list is free of internal conflicts. The IP-ICC Scheduler provide the instrument activity list to the spacecraft EOC Scheduler.

The EOC prepares the spacecraft subsystems' activity lists while other participants are preparing their final scheduling input. The EOC bases these lists on the preliminary resource schedule and any new input that has been received since the preliminary resource schedule was generated.

Finally, the EOC combines the instrument and spacecraft subsystem activity lists to construct the detailed activity schedule for the spacecraft and instruments. Each day it integrates the instrument activity lists and the spacecraft subsystem activity lists into a detailed activity schedule, using the latest information on spacecraft and SN resource. The EOC integrates all instruments' data rate requirements with the TDRSS schedule to create a recorder management schedule, which it includes in the detailed activity schedule. This integration may be facilitated by algorithms for the spacecraft recorder and for Communications subsystem management.

While generating a detailed activity schedule, the EOC may encounter conflicts between instruments or between an instrument and a spacecraft subsystem. Such conflicts can result from insufficient accounting of the new activities added since the generation of the preliminary resource schedule. The EOC Scheduler notifies the parties involved in the conflicts, who may first attempt to resolve the problem among themselves. If the EOC Scheduler, PI/TL or IP-ICC Scheduler cannot resolve the conflicts, the problem is referred to the project scientist for a decision.

When the detailed activity schedule is complete and conflict free, it is made available to all the participants, to be used as the basis for commanding. The detailed activity schedule is also made available to the DAAC for use by other EOSDIS elements and data requesters.

The EOC holds the detailed activity schedule for at least 7 days. During a spacecraft emergency, or as the result of a late change, onboard spacecraft activities may occur that the preexisting detailed activity schedule does not reflect (as described in Sections 3.4.3.6 and 3.4.3.7). In these cases, the EOC updates the detailed activity schedule within 24 hours of the execution of such activities so that the schedule accurately reflects actual events. After holding the schedule for 7 days, the EOC sends it to the GSFC DAAC for permanent archiving.

#### 3.4.3.6 Late Changes

Many phenomena of interest to the EOS mission cannot be predicted in advance. Moreover, they can change rapidly. Such events include volcanic eruptions, earthquakes, weather-dependent studies, and oil and chemical spills. Such events represent potential IP-instrument TOOs for the EOS mission and may require rapid changes to the existing schedule to enable the targets to be studied effectively. Other circumstances may require rapid late changes to the existing schedule: e.g., the loss of TDRSS contact time, spacecraft subsystem problems, or instrument anomalies. For scheduling purposes, TOOs and late changes require the same type of response and are treated in a similar manner.

Designation of a DAR as a TOO DAR for an IP instrument generally requires project scientist authority. However, the project scientist establishes policies and procedures that enable instrument operations personnel to identify most of the IP instrument TOO DARs and authorizes them to designate DARs as TOOs without needing project scientist involvement in every case. A TOO DAR of high priority (as specified in the LTSP and in consultation with the project scientist) would override a lower priority DAR that was already scheduled by the IP-ICC. If a DAR for a potential TOO causes science conflicts that cannot be resolved by the guidelines, it must be explicitly authorized by the project scientist to become an actual TOO DAR that is implemented by the FOT.

An example of a TOO is a volcanic eruption. This type of TOO can be preplanned, in that onboard resource needs (e.g., the instruments, spectral bands, and other resources involved) can largely be determined in advance and the commands necessary to implement the TOO observation, although incomplete (e.g., without time tag), can be generated, validated, and stored in the associated data base for later use. (Section 3.4.7.1 describes the data base.) When a volcano erupts, a science user submits a DAR through the DAAC to the IP-ICC. This DAR includes any additional information (e.g., the eruption's exact location, time windows for observations) necessary to complete a preplanned command set. The IP-ICC accommodates the DAR in a manner that depends on the time of its entry to the EOSDIS and its effects on the activities already scheduled.

The detailed activity schedule may undergo late changes for such reasons as the dependence of a scientific campaign on *in situ* observation (e.g., ship-based observation). DARs for such a campaign are scheduled throughout the initial and final scheduling process but may require late changes because the final ship locations or local conditions prevent coincident viewing by both the flight and ground instrumentation. In this case, the observation has to be rescheduled.

A TOO that enters the EOSDIS at least 24 hours before the actual observation is incorporated into a detailed activity schedule during the next final scheduling phase. The EOC Scheduler attempts to accommodate the TOO based on the currently active TDRSS schedule. The EOC Scheduler may have to defer or cancel activities previously scheduled for their respective instruments, or the project scientist may get involved to resolve the conflicts between instruments.

If a late change is received between 24 hours and 6 hours before the actual observation/activity, it is accepted for possible implementation if it does not conflict with the previously scheduled activities. It uses unallocated spacecraft resources and is accommodated within the existing TDRSS schedule. Time still exists for schedule updating and for command load generation and uplinking.

From 6 hours before the observation to 1 hour before the last TDRSS contact prior to the actual observation, the late change is accommodated if it requires only real-time commands. Typically, this is the case when the command load already has been uplinked but parameters need modification very close to the time of the observation. At this point, there may no longer be sufficient time for a careful ground system check of a completely new command load before uplink, or a TDRSS contact may not be available to uplink a new command load to the spacecraft.

The timing restrictions for late changes are based on worst-case scenarios in which additional TDRSS contact time is unavailable. In many cases, flight operations should be able to respond to late changes in much less time than the 24-, 6-, or 1-hour time limit just discussed. Schedule changes that have a sufficiently high priority or sufficiently low impact are accepted and scheduled if possible. The EOS MOM is responsible for ensuring that no changes are made to the schedule that would affect the health and safety of the spacecraft. If a late change is not covered by the long-term mission plans, the project scientist provides guidance.

#### 3.4.3.7 Post-emergency Scheduling

Emergency operations disrupt the detailed activity schedule. The flight operations team working with PIs/TLs, the project scientist, and the MOM, generates a new detailed activity schedule that gradually returns the spacecraft and its instruments to normal science operations from safemode operations. The basic sequence of such a schedule brings the spacecraft and instruments through increasing levels of functionality while allowing the FOT to verify that the spacecraft is operating correctly at each level. After spacecraft operations are successfully restored, the EOC Scheduler and/or PI/TL must verify that their instrument is functioning properly. SN resources required for conducting these activities are usually granted.

Emergency operations have varying degrees of severity. For example, a single instrument may place itself in safe mode because of an anomaly. Or the spacecraft may “safe” an instrument because of problems detected in the instrument housekeeping data. The spacecraft may place the entire spacecraft, including the instruments, in safe mode because of severe problems detected in one of the spacecraft subsystems. Any instrument or the entire spacecraft including all the instruments may be commanded to safe mode because of anomalies detected by analysis on the ground.

Normally, the detailed activity schedules are continuous extensions of each other. Under emergency operations, however, the preexisting detailed activity schedule is discarded, and a new detailed activity schedule has to be generated, possibly containing activities to bring the spacecraft and the instruments from safe mode back to normal operations. When the spacecraft and instruments recover from an emergency, all the participants--the EOC and PIs/TLs at the ISTs--begin the final scheduling process (fully described in Section 3.4.3.5) to create a new detailed activity schedule, based on the existing preliminary resource schedule.

Activities that were lost because of the emergency are resubmitted in the revised instrument activity list, if possible. The EOC notifies the IP-ICC of any DARs that could not be accommodated or that changed status as a result of the emergency.

#### 3.4.3.8 Sample Calendar for an Operational Day

Figure 3.4.3.8-1 is an example of the calendar of events leading to a typical operational day. In this example, the operational day (the day of execution of the commands of interest) is Sunday, April 15, and the target week (the week containing the operational day) is April 9 to 15. DARs for an IP instrument for April 15 are normally submitted by March 20, about four weeks before the target week. In this example, the weekly TDRSS schedule requests are generated on Fridays, and the EOC submits the TDRSS schedule requests early the following Monday mornings. On April 2 (1 week after the TDRSS schedule request was submitted), the NCC publishes the active schedule for the target week. On the same day (April 2), the EOC generates the preliminary resource schedule for the target week. The EOC and ISTs use the preliminary resource schedule to begin final scheduling for the target day. Final scheduling continues until Thursday (April 10), when the EOC issues the target day's detailed activity schedule for the spacecraft and instruments. Command data is due to the EOC on the next day (April 13). On April 13, the EOC assembles the target day's command load, which is uplinked on April 14, 1 day before the target day. After the detailed activity schedule has been issued, and up to 6 hours before the actual observation or activity, late changes can be accepted and rescheduled as appropriate.

Figure 3.4.3.8-2 is an example of a week of concurrent flight operations activities leading to onboard execution. Requests for the TDRSS schedule for another period is sent to the NCC; conflicts are resolved if necessary. Meanwhile, the daily final scheduling activity produces a detailed activity schedule 2 days in advance, commands are being generated about 1-2 days in advance, the load is being prepared for onboard execution 1-2 days in advance, and the next day's load is being uplinked. Rescheduling or regeneration of commands may have been necessitated by a late change. Monitoring and analysis activities associated with the onboard execution of the current day's load also take place. (Some of the daily scheduling and command generation activities for Saturday and Sunday are performed by Friday to reduce the weekend workload.)

### 3.4.4 Commanding

FOS commanding has the purpose of directing the spacecraft and instruments to perform the activities as scheduled or as needed. This function has three major threads of activities:

- Normal commanding, which implements the spacecraft and instrument activities that have been specified in the detailed activity schedule
- Implementation of late changes to the scheduled course of activities as necessitated by late changes to the detailed activity schedule
- Emergency/contingency commanding required for safe operation of the spacecraft and instruments

| | MONDAY | TUESDAY | WEDNESDAY | THURSDAY | FRIDAY | SATURDAY | SUNDAY | |
|---|---|---|---|---|---|---|---|---|
| | EOC continues to accept IP-ICC DAR Activities for target week<br>MARCH 19 | IP-ICC DAR Activities due to EOC for target week<br>MARCH 20 | EOC/ISTs prepare inputs to preliminary resource schedule<br>MARCH 21 | Inputs to preliminary resource schedule due<br>MARCH 22 | EOC prepares TDRSS schedule request for target week<br>MARCH 23 | MARCH 24 | MARCH 25 | NCC Forecast Scheduling <==Period |
| | EOC submits TDRSS schedule request to NCC<br>MARCH 26 | EOC possibly negotiates with NCC<br>MARCH 27 | MARCH 28 | MARCH 29 | MARCH 30 | MARCH 31 | APRIL 1 | |
| | NCC activates TDRSS schedule and sends to EOC<br>APRIL 2 | APRIL 3 | EOC/ISTs work on their detailed activities<br>APRIL 4 | Continue working on detailed activities<br>APRIL 5 | • • •<br>APRIL 6 | • • •<br>APRIL 7 | • • •<br>APRIL 8 | NCC Active Scheduling <==Period |
| Target Week==> | • • •<br>APRIL 9 | • • •<br>APRIL 10 | • • •<br>APRIL 11 | EOC issues detailed activity schedule for April 15<br>APRIL 12 | Commands or command information due EOC performs its Command/ Load Generation<br>APRIL 13 | Uplink<br>*...Late*<br>APRIL 14 | Operational Day (Execution)<br>*Changes...*<br>APRIL 15 | |

***Figure A.3.8-1. Sample Calendar of Events Leading to an Operational Day***

| Activities for Monday MARCH 26 | Activities for Tuesday MARCH 27 | Activities for Wednesday MARCH 28 | Activities for Thursday MARCH 29 | Activities for Friday MARCH 30 | Activities for Saturday MARCH 31 | Activities for Sunday APRIL 1 |
|---|---|---|---|---|---|---|
| Continue accepting IP-ICC DAR activities for week of 4/16; | IP-ICC DAR due for week of 4/16; | Continue accepting IP-ICC DAR activities for week of 4/16; | Continue accepting IP-ICC DAR activities for week of 4/23; | Continue accepting IP-ICC DAR activities for week of 4/23; | | |
| EOC/IST preliminary resource estimate for week of 4/16 | EOC/IST preliminary resource estimate for week of 4/16 | ISTs prepare inputs to prelim. resource schedule for week of 4/16 | EOC collects input to preliminary resource schedule for week of 4/16 | EOC generates preliminary resource schedule & prepares TDRSS request for week of 4/16 | | |
| EOC submits to NCC TDRSS request for week of 4/9; EOC receives and distributes active TDRSS schedule for week of 4/2 | EOC/ISTs work on detailed activities for week of 4/2; EOC possibly negotiates with NCC | EOC/ISTs work on detailed activities for week of 4/2; EOC possibly negotiates with NCC | EOC/ISTs work on detailed activities for week of 4/2; EOC possibly negotiates with NCC | EOC/ICC/ISTs work on detailed activities for week of 4/2; EOC possibly negotiates with NCC | | |
| EOC issues detailed activity schedule for 3/29 | EOC issues detailed activity schedule for 3/30 | EOC issues detailed activity schedule for 3/31 | EOC issues detailed activity schedule for 4/1 | EOC issues detailed activity schedule for 4/2-4/4 | | |
| EOC/ISTs work on cmds or cmd info for 3/8 | EOC/ISTs work on cmds or cmd info for 3/29 | EOC/ISTs work on cmds or cmd info for 3/30 | EOC/ISTs work on cmds or cmd info for 3/31 | EOC/ISTs work on cmds or cmd info for 4/1-4/3 | | |
| EOC cmd/load gen for 3/28 | EOC cmd/load gen for 3/29 | EOC cmd/load gen for 3/30 | EOC cmd/load gen for 3/31 | EOC cmd/load gen for 4/1-4/3 | | |
| Uplink for 3/27 | Uplink for 3/28 | Uplink for 3/29 | Uplink for 3/30 | Uplink for 3/31 | Uplink for 4/1 | Uplink for 4/2 |
| Resched or regen of commands for 3/26-27 | Resched or regen of commands for 3/27-28 | Resched or regen of commands for 3/28-29 | Resched or regen of commands for 3/29-30 | Resched or regen of commands for 3/30-31 | Resched or regen of commands for 3/31-4/1 | Resched or regen of commands for 4/1-4/2 |

***Figure A.3.8-2. Sample Concurrent FOS Activities Over 1 Week***

Commanding also involves activities of command data validation, command verification, onboard memory management, and command history maintenance.

#### 3.4.4.1 Background

The instruments and spacecraft subsystems require various types of ground commanding support, depending on the level of their operational autonomy. In particular, some instruments and subsystems rely on external commanding; others do not.

Some instruments rely exclusively on external commanding for their operations. These instruments do not have embedded computers; commanding support for such instruments is normally implemented via commands that are stored in the spacecraft's SCC memory and that are dispatched and executed only at appropriate times. Such commands are collectively termed "SCC-stored instrument commands" and are typically composed of absolute time commands and relative time sequences. An absolute time command has associated with it a well-defined execution time. A relative time sequence is a reusable set of commands that, in most cases, performs a specific function, such as "set up and start a calibration operation." Commands within a relative time sequence are separated by time delays that can be individually set. A relative time sequence can be activated by a real-time command or by a stored command. Some SCC-stored instrument commands may need data tables that are also stored in the SCC memory. Such data tables are termed "SCC-stored instrument tables."

Other instruments need little or no external commanding because they have embedded computers that direct and control the instrument operations. For such instruments, ground commanding support takes the form of uploading of instrument software update and associated instrument data and/or command tables to be used by the instrument software. An instrument command table contains a sequence of commands that typically performs a specific function on the instrument (e.g., closing a sensor cover before an orbit maneuver or changing mode to standby) and can be initiated by a SCC-stored command or by the instrument software. An instrument command table can also be used for stored commands, which may include absolute time commands and/or relative time sequences. An instrument data table usually contains parameters (e.g., gain/threshold setting) that are used by the instrument software to optimize or control the instrument performance. For some instruments, instrument data tables are used as the primary means of controlling instrument operations. The instrument software, instrument command tables, and instrument data tables can usually be modified and uploaded from the ground; these are collectively termed "instrument loads." In addition, some of these instruments require external commands to change their operating states or modes. (For example, it may remain operating in a certain mode until commanded otherwise from outside.) For such an instrument, additional commanding support can be implemented by SCC-stored instrument commands and associated data tables or by real-time instrument commands.

Most of the spacecraft subsystems require only limited commanding support from the ground during normal spacecraft operations. The SCC software achieves such operational autonomy for the Guidance, Navigation, and Control (GN&C); Electrical Power; Thermal Control; and Propulsion subsystems. Ground commanding support is implemented via occasional uploading of SCC software updates and associated data tables.

Other subsystems do require commanding support from the ground for their normal operations. Some Communications subsystem components (e.g., Ku-band modulator and transmitter) and some C&DH subsystem components (e.g., recorders) are commanded from the ground during a TDRSS contact period to switch their operational states. Normally, commanding support for the operation of these components is implemented via both real-time and stored commands. In addition, SCC software updates and associated SCC-stored tables (e.g., TDRSS ephemeris table for high-gain antenna (HGA) pointing) are occasionally uploaded.

Additional real-time ground commanding support is required for both the instruments and the spacecraft subsystems in emergency/contingency situations.

Table 3.4.4.1-1 lists eight command data types and their respective destinations and potential sources. These are discussed in the remainder of this section.

The assignment of commanding responsibilities for each instrument to the PI/TL and EOC is negotiated before launch, although certain responsibilities may migrate from the PI/TL to the EOC during the mission operations phase.

An instrument may use commands and tables that are stored in the SCC, the instrument, or both. For complex instruments, some of these commands/tables require frequent updating. Such updating is part of routine operations performed at the EOC. The EOC uses command information provided by the instrument engineering team via the IST. In contrast, the commands and tables for non-complex instruments typically do not change often. It is likely that the instrument engineering team generates these updates and provides them to the EOC via the IST; it is also possible that the PI/TL may delegate this responsibility to the EOC under normal conditions.

***Table 3.4.4.1-1. Command Data Types***

| Command Data | Destination | Source |
|---|---|---|
| SCC-Stored Instrument Command | Instruments | EOC/IST* |
| SCC-Stored Instrument Table | SCC (used for instrument operations) | EOC/IST* |
| Instrument Load | Instruments (with embedded computers) | IST*/EOC |
| Real-Time Instrument Command | Instruments | IST* (via command request); EOC |
| SCC-Stored Spacecraft Command | Spacecraft subsystems | EOC, FDF |
| SCC-Stored Spacecraft Table | SCC (Used for spacecraft subsystem operations) | EOC, SDVF, FDF |
| SCC Software Update | SCC | SDVF |
| Real-Time Spacecraft Command | Spacecraft subsystems (e.g., Communications Subsystem, Recorders) | EOC |

*IST refers to the PI/TL or instrument engineering team using the IST.

The instrument engineering team updates the instrument software and provides the updates to EOC via the IST.

The EOC is responsible for the real-time instrument commanding of instruments under their control. The PI/TL may request the EOC to initiate real-time commands. For spacecraft subsystem commanding support, the EOC is largely responsible for generating, validating, and maintaining the command data. The SCC software is the responsibility of the SDVF. For TONS operations and orbit adjustment operations, the FDF provides the EOC with the required parameters. The EOC incorporates the appropriate parameters into SCC-stored spacecraft commands and SCC-stored spacecraft tables.

The EOC generates instrument command loads, using the command specification and command information in the spacecraft data base (SDB). Examples of higher level command specification include command mnemonics or the name of a group of related commands.

#### 3.4.4.2 Normal Commanding

Normal daily commanding for the spacecraft and its instruments is based on the detailed activity schedule. For the most part, this involves the use of stored commands and instrument loads; certain types of support need real-time commands as well. Figure 3.4.4.2-1 shows the relationships among the various command data which is the end product generated from the detailed activity schedule. When used with Table 3.4.4.1-1, the figure identifies the destination and potential sources of each end item.

The appropriate instrument command data for a given day are generated about 2 days before they are needed. When command data are generated, a header is attached to each logical unit of the command data. The EOC uses these headers to validate the command data generated by requests received from ISTs. The headers are removed when the command data are combined into an integrated baseline command data set. In accordance with the commanding responsibilities assigned to the PIs/TLs and/or the EOC each participant generates instrument command requests and includes them in the detailed activity schedule. The PI/TLs validate these requests and provides them to the EOC, either directly or via the IST, as appropriate. The instrument command requests are validated by the source entity as well as by the EOC before being integrated into the baseline command data set.

When the detailed activity schedule is complete, the EOC converts the appropriate portions of the detailed activity schedule into spacecraft subsystem command data, which consist of SCC-stored spacecraft commands, SCC-stored spacecraft tables, and real-time spacecraft commands. This EOC activity may require externally supplied parameters (e.g., parameters from the FDF for orbit maneuvers or TONS operations). The EOC attaches time tags or timing information to the commands being generated. If it is required in the detailed activity schedule, the SDVF provides the EOC with an SCC software update and its image. If an instrument microprocessor load is required in the detailed activity schedule, the PI/TL provides the EOC with the microprocessor load data.

The EOC assembles the instrument command data and spacecraft command data. The EOC also generates a ground script, which controls routine EOC functions during real-time contacts, from the detailed activity schedule.

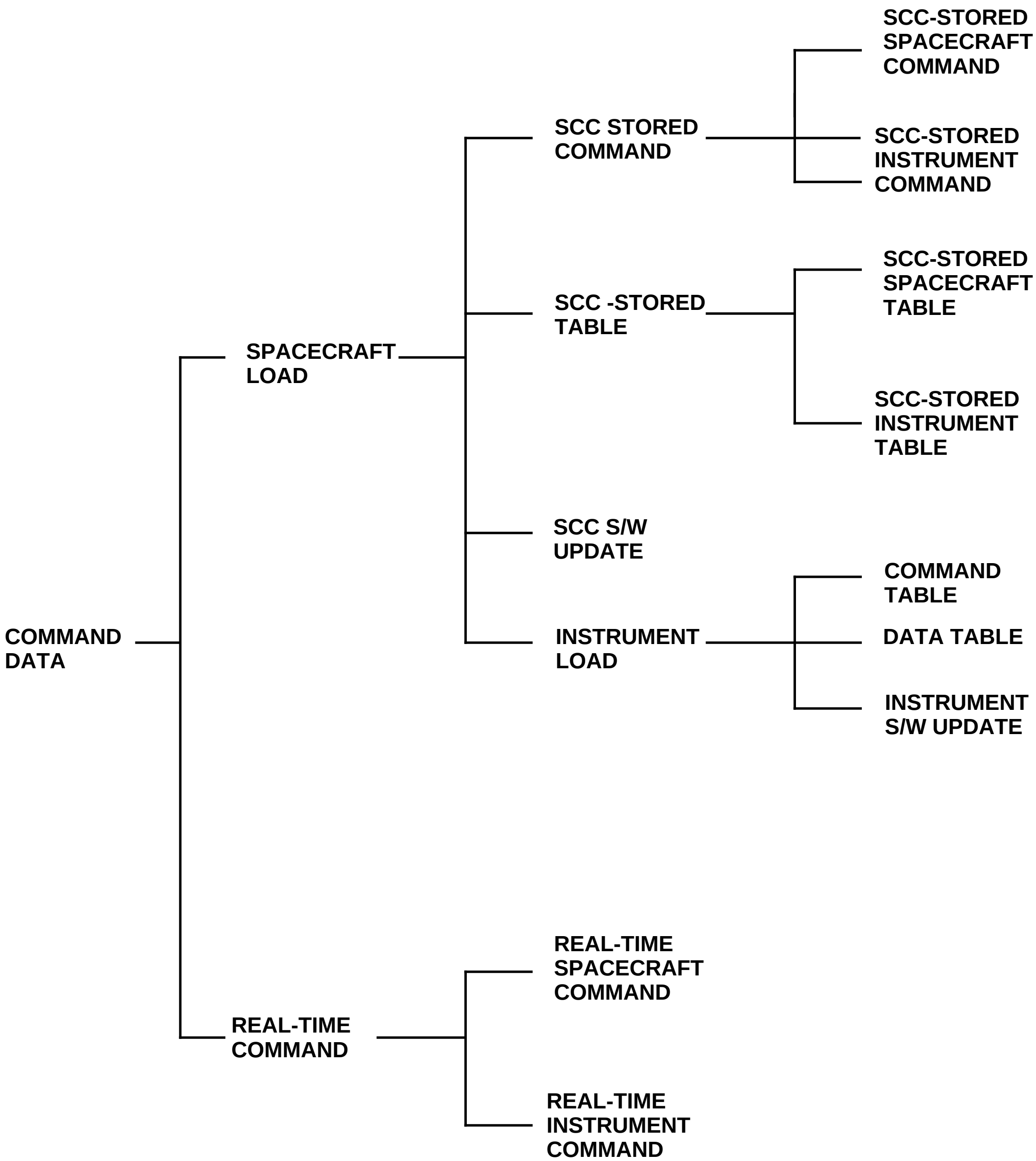



*Figure 3.4.4.2-1. Baseline Command Data Set Composition*

Sometime before the start of the target day, the spacecraft load is uplinked to the spacecraft by the EOC during a TDRSS contact. During the forward link, normal real-time commanding required in the detailed activity schedule is also being conducted. Examples of normal real-time commanding support include turning on or off the Ku-band transmitter, initiating and terminating the spacecraft recorder playback, and preparing communications devices for the next TDRSS contact.

#### 3.4.4.3 Late Command Changes

Accommodation of late changes (including IP instrument TOOs) to scheduled activities may require late changes to the command data that has already been generated and whose spacecraft load may have been uplinked.

Late changes that enter EOSDIS between 24 and 6 hours before the actual activities are accommodated if they do not conflict with previously scheduled activities. The detailed activity schedule is updated, a new baseline command data set generated, and the new spacecraft load uplinked.

Some late changes that enter EOSDIS later than 6 hours before the activities but sooner than 1 hour before the next TDRSS contact are accommodated if they require only real-time commands. Most such events are preplanned and have command sequences in the appropriate data base. The EOC edits the commands, if required, and uplinks the resulting commands to the spacecraft. For late changes that have not been preplanned, the EOC may generate and uplink the required commands quickly. However, this must be accomplished in a manner that does not subject the mission to undue risk.

Late changes that are of high enough priority and low impact can be accommodated in less time than discussed above, if, in the judgment of the EOC operations personnel working under the direction of the MOM and the project scientist, they do not pose any risk to the already scheduled activities.

#### 3.4.4.4 Emergency/Contingency Commanding

Emergency/contingency commanding is real-time commanding needed in rapid response to a detected failure or an unsafe or potentially unsafe condition. Emergency/contingency commands are uplinked at the next available TDRSS contact. In the unlikely event that waiting until the next scheduled TDRSS contact threatens safety, a request can be made to the NCC for an emergency TDRSS contact. Such an emergency contact may be requested to occur as soon as 10 minutes after the request is made. If no TDRSS contact is available within the requested time frame, the NCC attempts to schedule an alternate link via DSN, WOTS, or GN. Emergency/contingency commanding may also be used during initial spacecraft or instrument checkout.

Emergency/contingency commanding of spacecraft supported through DSN/GN/WOTS (e.g., CHEM) follow a similar scenario for scheduling the next available contact as those supported primarily using TDRSS. If safety is compromised by waiting until the next scheduled DSN/GN/WOTS contact, a request can be made to the NCC for an emergency contact.

Emergency/contingency commanding for an instrument is conducted from the EOC. The EOC may initiate emergency/ contingency commanding on its own, based on the results of instrument monitoring. Alternatively, the PI/TL or the instrument engineering team can request the initiation of real-time commanding by submitting a command request to the EOC through the IST. Whenever practical, commands required for such a situation are preplanned and stored in the data base for later use. If no preplanned commands are available, the EOC needs to generate and uplink the required commands quickly, although this must be done in a manner that does not subject the mission to undue risk. When initiated, emergency/contingency commands are validated and are uplinked by the EOC at the appropriate time. The EOC then evaluates the instrument housekeeping or engineering data to verify that the instrument has executed the emergency/contingency commands correctly.

The EOC performs emergency/contingency commanding of the spacecraft and of the instruments under its control, and also performs limited safeing-related commanding of the instruments. On determining that real-time commanding is required, the EOC prepares real-time commands, uplinks them at the next TDRSS/DSN/GN/WOTS contact, and then monitors the return-link telemetry to verify the receipt and execution of the commands.

An onboard capability allows the inhibiting of some or all stored commands that are yet to be executed. Correct use of this capability prevents such stored commands from interfering with the execution of emergency/contingency commands.

#### 3.4.4.5 Command Validation

All spacecraft and instrument command data are validated on the ground before they are uplinked. Command data undergo two levels of validation: a high level accomplished by header checking, and a detailed level accomplished by constraint checking and sometimes requiring simulation as well (for more complex instruments or subsystems).

Command validation via header checking is performed by the EOC on uplink data (e.g., commands, table loads, software loads) from external sources. The header, created when the uplink data are generated, establishes the relationship with the detailed activity schedule from which the uplink data were generated. The header also contains information regarding source and destination, identification of critical operations, and expected spacecraft resource utilization. In addition, it may contain time information for the commands or details about the organization of the uplink data that follow the header.

The EOC checks the headers of the uplink data for authorization, schedule consistency, and identification of any critical operations, the last because critical commands require explicit authorization by the FOT before uplink. The critical commands may have to be scrutinized at the bit level against those in the data base (Reference Section 3.4.7.1). Spacecraft resource usage is also checked against the limits established in the detailed activity schedule.

Constraint checking for an instrument or a spacecraft subsystem is the process of determining whether the uplink data violate any operational constraints of the instrument or the spacecraft subsystem. Constraint checking constitutes part of the command generation process. Examples include verifying that certain pairs of commands are separated by a specified time interval and that a parameter value of a certain command is within predetermined limits. In general, spacecraft and instrument constraints are defined before launch with information provided in the data base. For operationally complex instruments or subsystems, a detailed level of command validation may require access to simulation within the EOC.

#### 3.4.4.6 Command Verification

The FOS is responsible for command verification for all commanding support it provides. The FOS performs three levels of command verification: receipt, storage, and execution.

Command receipt verification is the process of verifying complete, correct, and in sequence delivery of the command data from the ground to the C&DH. The use of the CCSDS telecommand transfer layer service facilitates delivery of the command data to the C&DH without error, without omission or duplication, and in the same sequential order as the one in which they were sent (by the EOC).

Command storage verification is the process of verifying the delivery of the SCC-stored command data or instrument loads to their destination for storage. For this purpose, the SCC or instrument computers use a cyclic redundancy code (CRC) checksum technique on uplinked command data as stored in the SCC or instrument memory. The results of these checks are reported in the housekeeping data stream, allowing the EOC operations personnel to take action as needed. If command storage verification finds that a bad load has entered the SCC or instrument memory, the EOC follows procedures that have been predefined for such occasions. These procedures are likely to include retransmission of the load to the spacecraft and (if the problem persists) initiation of diagnostics.

Command execution verification is the process of verifying both the execution of a command by the destination entity and the attainment of the desired effect on the system as a result. This type of verification relies on the return-link telemetry. For real-time or stored commands destined for spacecraft subsystems or instruments, the EOC evaluates appropriate housekeeping and/or engineering parameters to verify that the commands have been executed. For example, housekeeping status data are associated with each relay drive or logic level command, allowing explicit verification of the command execution. Telemetry processing of various levels is required to verify whether execution of the instrument load is producing the intended effects on the instrument system.

#### 3.4.4.7 Onboard Memory Management

Flight operations manages the SCC memory of the spacecraft; it may also manage the onboard memories of instruments that have embedded computers if this responsibility has been negotiated with the appropriate PIs/TLs during the mission planning phase. Memory management includes keeping track of software, data tables, and stored commands, and accounting for areas of memory that have been determined to be unusable.

Spacecraft SCC memory management is the responsibility of the EOC. From the management viewpoint, the SCC memory consists of two parts: a data area and a software area. The data area contains stored commands and tables that are periodically updated, and the EOC is responsible for managing its contents. The software area of the SCC memory contains the flight software and is maintained by the spacecraft contractor.

For instruments whose operations are controlled from an embedded computer, the instrument memory must be managed. As with the SCC memory, the instrument memory may be considered as comprising a data area and a software area. The data area may consist of instrument command tables and/or data tables and may be managed by the EOC or by the instrument engineering team at the IST, as negotiated with the PI/TL. For example, tables that are relatively easy to interpret may be maintained by the EOC; others are likely to be maintained by the instrument engineering team. The EOC can check the contents of the instrument software area against its ground image as part of instrument anomaly investigation. Beyond this, the instrument engineering team has the responsibility for analyzing the meaning of the memory contents. For example, anomalies associated with the instrument software failure are analyzed and corrected by the instrument engineering team because it is responsible for the instrument software and its updates.

#### 3.4.4.8 Command History

The EOC maintains a log of all uplink activities, which includes for each uplink activity the command data uplinked, the start and end times, and its receipt by the C&DH. The EOC also maintains information on whether stored command data are correctly stored in the SCC memory and information on whether the SCC-stored commands are executed successfully by the intended destination entities under the EOC's control. For real-time commands, the EOC maintains information regarding command execution by the spacecraft subsystems and by the instruments under its control.

The EOC is also responsible for maintaining information on whether the SCC-stored or real-time instrument commands are successfully executed by the instrument. For applicable instruments, the EOC is responsible for maintaining information on whether the instrument load is correctly loaded and executed.

The command histories from the EOC and other uplink activity logs are kept at the EOC for 7 days. After a week, the command histories and logs are sent to the GSFC DAAC for archiving.

### 3.4.5 Monitoring

Flight operations monitoring focuses on determining whether the flight segment is healthy and, if so, whether its activities are progressing according to the schedule. The FOS implements remedies to anomalous conditions or improper operations through commanding, possibly preceded by analysis. The impacts of failure to remedy such conditions are reflected in the subsequent flight operations through planning and scheduling activities.

Flight operations monitoring activities include:

- Monitoring of instruments at the EOC with PI/TL participation via the ISTs (the degree of monitoring determined by the needs of the instrument)
- Monitoring at the EOC of the condition of the spacecraft subsystems and the overall health and safety of the spacecraft and its instruments

- Monitoring of the overall mission at the EOC

For instrument monitoring, the EOC uses spacecraft and instrument housekeeping data and instrument engineering data. Depending on the instrument, the EOC may need instrument memory dump data for instrument monitoring. For spacecraft monitoring, the EOC uses spacecraft housekeeping data under normal circumstances, and safemode housekeeping data and SCC memory dumps while the spacecraft is in safe mode (safe mode and safemode housekeeping data are defined in Section 3.4.5.2). The EOC also monitors the health and safety of the spacecraft and its instruments as a whole, using spacecraft and instrument housekeeping data.

#### 3.4.5.1 Instrument Monitoring

The responsibility of monitoring the operations of the U.S. instruments onboard U.S. spacecraft is divided between the FOT at the EOC and the PI/TL using the IST toolkit. Mission critical monitoring to verify whether the instrument is operating within prescribed limits without any adverse impact on spacecraft and other instruments is the responsibility of the EOC. A set of functions is available to the PI/TL via the IST, allowing them to participate in instrument monitoring, if desired.

Detecting and reacting to an instrument’s anomalous conditions involves several levels:

- The instrument’s hardware logic and/or instrument computer software monitors the instrument’s behavior. The anomalous conditions usually call for an immediate response (e.g., within a second) from the instrument. A response could be redundancy switching or placing the instrument into a safe mode.
- The SCC monitors instrument housekeeping data and, on detecting an anomaly, may issue a predetermined sequence of commands to the instrument. Response time is typically less than a few seconds.
- EOC monitors instrument housekeeping data. Anomalies detected from this activity are usually less severe than the two types of anomalies just described. The response time ranges from several seconds to hours.
- EOC monitors instrument engineering data. This monitoring is concerned more with the instrument’s performance (i.e., its scientific utilization) than with its health and safety.

If an anomalous condition is detected at any level and becomes persistent, the EOC and the PIs/TLs at the ISTs participate in diagnosing the problem and in developing a recovery procedure while the instrument remains in a safe condition. In case of an anomaly, the PI/TL provides the EOC with instructions on measures to be taken in response to the anomaly.

The following is a description of how each input data type is received, processed, and used in instrument monitoring activities within the EOC with PI/TL participation.

**Instrument Housekeeping Data.** Instrument housekeeping data includes health and safety parameters such as instrument on/off status, mode status, critical temperatures, and voltage and current at the instrument power supply. These data require expedient processing.

Instrument housekeeping data are available on the ground as part of the housekeeping packets. During the TDRSS contact period, the EOC receives real-time housekeeping packets that, taken together, cover up to 20 minutes per orbit in one or two contacts. Thus, for each orbit the EOC normally has at least one real-time snapshot of the instrument housekeeping stream. This provides adequate sampling for the instrument housekeeping parameters in that anomalies detected through housekeeping parameter monitoring can often wait for EOC action without causing damage to the instrument. In contrast, the playback housekeeping packets that have been collected from the end of the last TDRSS contact to just before the start of the current TDRSS contact are delivered to the EOC with a delay of a few minutes to hours after the contact. The delay depends on the EDOS requirements.

The EOC receives housekeeping packets from EDOS and extracts instrument housekeeping data and relevant spacecraft subsystem parameters from the received housekeeping packets. Spacecraft subsystem parameters extracted at the EOC include time, attitude, orbit, bus status, and other parameters, as specified in the data base. (Section 3.4.7.1 describes the data base.) If requested, the EOC forwards instrument housekeeping data and relevant spacecraft subsystem parameters to the instrument engineering team, via the IST, as those parameters are being retrieved.

The EOC uses discrete instrument housekeeping parameters to determine instrument status such as on/off status and operational mode. Nondiscrete instrument housekeeping parameters are converted into engineering units (EUs) (e.g., Kelvin, volts). The raw or EU-converted nondiscrete parameters may undergo checking for limits such as high/low limits, delta limits, and rail limits (the Glossary defines these terms); when a limit violation is detected, an FOT member or the instrument operations team is notified immediately via displays. The operations personnel may respond to alarms by initiating emergency commanding at the next forward-link opportunity to bring the instrument to a safe mode. A record of such events is entered in the instrument operations history log, and includes such details as the time of occurrence, duration, and actions taken. The instrument housekeeping parameters, either in raw or EU-converted form, are provided to the PI/TL or instrument engineering team via the IST on request.

Instrument monitoring routinely includes short-term trend analysis of the instrument housekeeping parameters. For example, as parameter values are available in real time, they are plotted against time and are evaluated by the FOT or instrument operations team. This kind of analysis may reveal incipient instrument faults enabling the FOT or instrument operations team to respond before the onboard spacecraft processor does. This avoids a potentially larger impact on overall mission operations.

Not all commands can be verified via instrument housekeeping data. However, for targeted instruments plotting on/off status and operational mode against time provides a high-level means of quickly verifying instrument command execution.

The history log receives the accumulation of high-level instrument operations status information including the results of short-term trend analysis and spacecraft subsystem information extracted from the spacecraft housekeeping data. On request, the EOC provides any data in the instrument history log to the PI/TL via the IST.

**Instrument Engineering Data.** Instrument engineering data are the primary input for instrument monitoring because they are designed to be the best representation of the instrument's condition. Instrument engineering data consist of instrument-specific hardware performance/ status information that is critical to the instrument science data. A portion of instrument memory, if downlinked on a regular basis, is considered part of the instrument engineering data stream. Instrument engineering data are recorded on the onboard recorders and are downlinked via a Ku-band single access (KSA) return-link service. Instrument engineering data are processed off line to detect subtle anomalies, which do not require as quick a response from the ground as do anomalies found during instrument housekeeping data monitoring.

For some instruments, instrument engineering data are available at the EOC either as separate packets or as part of a science packet. If engineering data are embedded in the science data stream, the DAAC receives the entire science data stream from EDOS and extracts instrument engineering data from the science data packets. Instrument engineering packets (or science packets containing engineering data) are production-processed by EDOS and available for delivery to the DAAC within 21 hours of receipt of all required data for production processing. The instrument engineering data may be retrieved at a rate compatible with the EOC processing capacity.

The EOC decommutates the packets (instrument engineering packets or science packets) to identify and extract instrument engineering parameters. It obtains information from the data base regarding data item types and locations within the science data or instrument engineering packets, as well as other information for subsequent processing. The EOC converts the data to the necessary EUs, generates derived parameters, and determines discrete states from the raw, nondiscrete, instrument engineering data, as defined in the data base. It uses discrete status data to determine the instrument operational mode (e.g., normal, standby, warm-up, calibration) and the configuration pertaining to the operational mode. For each operational mode (and configuration), the EOC performs various limit-sensing operations on the raw or EU-converted nondiscrete instrument parameters. It reports limit violations to the FOT or instrument operations team for evaluation and records them in the instrument operations history log. The operator may change limit definitions for specific parameters, either in accordance with long-term trends established by the instrument engineering team or in an ad hoc manner seen fit by the FOT or instrument operations team for evaluating the instrument behavior. The PI/TL can use the IST for access to raw or EU-converted instrument engineering data.

The EOC performs routine instrument parameter analyses as required for operations. Analyses of instrument engineering parameters (e.g., statistical analysis or correlation analysis) usually requires a complete set of engineering parameters over a certain period of time (e.g., over an orbit, a day, or a week), and has to wait until necessary input data are available. Such analyses are expected to be performed on small sets of data such as from one orbit or 1 day, or on a few parameters spanning a much longer time period (e.g., 1 month or even 1 year). Such data is stored at the EOC as long as necessary. However, even with an incomplete set of data, the EOC may determine such quantities as maximum, minimum, mean, and standard deviations and may compare them with those obtained from previously computed values. Or, the EOC can generate such plots as one parameter value versus time or one parameter value versus another (scatter plot), and examine whether a parameter or group of parameters is behaving normally. The instrument engineering team  conducts a thorough analysis (as described in Section 3.4.6.2), which requires greater instrument engineering expertise. This team can use the IST to obtain instrument engineering or housekeeping data and analyze them, using either routine IST analysis tools or tools provided by the instrument engineering team itself.

The EOC stores instrument status/configuration and telemetry parameters in the instrument operations history log. The data in the history log may be retrieved for routine analysis at the EOC or for intensive study at the PI/TL's location. The history log data that are one week old is shipped periodically (perhaps once a day) to the GSFC DAAC for archival.

**Science Data.** Monitoring of an instrument's condition is based on two assumptions: (1) the instrument is healthy if the instrument engineering data so indicate, and (2) a healthy instrument acquires scientifically useful data. Thus, it is imperative that the set of engineering data be chosen carefully for its design and that these two assumptions be validated by thorough pre-launch testing. Some instruments, however, may acquire data of dubious scientific utility even if their engineering data indicate that they are healthy. To discover such situations, the EOC or the PI/TL must be able to scrutinize at least a subset of the instrument science data.

Science data sets are delivered directly to the DAAC before they are available to the EOC. Products that are not routinely received from the DAAC must be requested by the EOC via the submission of a data product request. The DAAC,  with the support of the SMC, negotiates with the EOC if it cannot meet the requested time of delivery.

Evaluation at the EOC involves following the prescribed instructions provided by the instrument science team. When evaluation detects anomalous behavior, or if the EOC has been notified of anomalies that were found during DAAC product quality assessment, the FOT or the instrument operations team takes appropriate actions if procedures for such actions have already been established. If resolution of the problem is beyond the EOC expertise, the problem is referred to the concerned instrument engineering team at the IST. This scenario is likely because the problems uncovered through evaluation, if not manifested in the instrument engineering data, are expected to be difficult to resolve because the correlation between the engineering data and the problem is not immediately obvious. This situation requires intensive study by the instrument engineering team at the IST/SCFs. The instrument engineering team has access to the science data for display or for further processing using their own tools. The instrument engineering team evaluate the information and provide the EOC with instructions for resolving the problem. Such instructions may result in instrument commanding.

**Instrument Memory Dump.** For instruments that are capable of dumping some or all of their memories, the EOC may use memory dump data for investigating anomalous instrument behavior. For storage verification of instrument loads during normal operations, the EOC uses a CRC checksum technique (Section 3.4.4.6). Instrument memory contents are typically dumped when instrument failures or anomalies are detected during routine instrument monitoring activities and the causes are not easily identified. The instrument may be commanded to provide several copies of its memory contents to guard against transmission errors.

The EOC maintains a ground image of the expected instrument memory. On receiving multiple copies of the memory dump, the EOC determines the best estimate of the memory contents and compares the memory dump bit by bit with the corresponding ground image. If the EOC finds discrepancies between the instrument microprocessor loads and the ground image, the EOC notifies, via the IST, the PI/TL for subsequent action. If errors in the instrument software are suspected to be a cause of an anomalous instrument behavior, the EOC sends the dump and ground image data to the instrument engineering team at the IST for further analysis (Section 3.4.6.2).

The instrument engineering team uses the instrument memory dump and instrument engineering data to analyze instrument status or anomalies. Anomalous instrument behavior may reveal permanently damaged memory areas. These are recorded as such in the data base so that their future use may be avoided.

#### 3.4.5.2 Spacecraft Monitoring

The EOC is responsible for monitoring the condition of all spacecraft subsystems and the overall health and safety of the spacecraft and its instruments. The EOS-AM-1 spacecraft contains seven subsystems:

- Communications
- C&DH
- Structure/mechanisms
- Electrical power
- Thermal control
- GN&C
- Propulsion

Other EOS spacecraft are expected to have subsystems or modules that perform functions equivalent to the subsystems listed above. Under normal conditions, most of the spacecraft subsystems (e.g., GN&C, Electrical Power subsystem [EPS]) operate in a relatively autonomous manner, whereas others (e.g., K-band modulator and transmitter) need to be commanded from the ground. Even this limited spacecraft subsystem autonomy can be overridden and the operation controlled from the ground.

The SCC (within the C&DH subsystem) performs onboard monitoring and control, using a subset of housekeeping data that consist of all spacecraft subsystem data and instrument housekeeping data. On detecting a failure, the SCC attempts to reconfigure the spacecraft using built-in redundancies to restore normal operations. If this fails, the SCC brings the affected spacecraft subsystem modules or instruments into safehold condition. In case of major spacecraft failures (e.g., a failure in the EPS or in the SCC itself), the SCC places the entire spacecraft and its instruments into a safe mode. The spacecraft safe mode is defined as the spacecraft operational mode where the spacecraft is in safehold condition with limited or no science operations being performed. The SCC may still be in control of the spacecraft operations; it must transfer control to the safemode handling module if the SCC itself fails. The housekeeping data gathered while the spacecraft is in safe mode are called safemode housekeeping data.

The EOC has access to housekeeping packets (real-time and playback) to investigate and act on anomalous conditions that the SCC overlooked or could not handle. Real-time housekeeping data are normally available whenever a TDRSS/GN/DSN/WOTS return-link service is available. All housekeeping data, including data downlinked in real time, are stored in the recorders for later playback.

In addition to housekeeping packets gathered during normal spacecraft operation, the EOC has access to SCC memory contents and safemode housekeeping data. The EOC uses these in spacecraft monitoring.

**Spacecraft Housekeeping Data.** Housekeeping packets constitute the principal input needed at the EOC for monitoring the spacecraft subsystems and the overall health and safety of the spacecraft and its instruments. During the TDRSS contact period, the EOC receives real-time housekeeping packets that, taken together, cover up to 20 minutes per orbit in one or two contacts. Thus, for each orbit, the EOC normally has at least one real-time snapshot of the spacecraft housekeeping stream. This provides adequate sampling for the spacecraft housekeeping parameters in that anomalies detected through housekeeping parameter monitoring can often wait for EOC's action without causing damage to the spacecraft subsystem(s). In contrast, the playback housekeeping packets that have been collected from the end of the last TDRSS contact to just before the start of the current TDRSS contact are delivered to the EOC with a delay of a few minutes to hours after the contact. The delay depends on the EDOS requirements. Thus, the playback spacecraft housekeeping data may be more useful for analysis (e.g., trending) than for health and safety monitoring of the spacecraft.

The EOC receives housekeeping packets from EDOS via Ecom. It decommutates the packets to sort out nondiscrete raw spacecraft subsystem parameters and other discrete status data or flags. The EOC extracts orbit information and attitude sensor data from the housekeeping packets and provides them to the FDF. It converts raw nondiscrete spacecraft and instrument housekeeping data into EUs and uses discrete status data to determine corresponding status parameters (on/off or operation mode). Discrete status parameters define an operations configuration of the spacecraft, and nondiscrete parameters represent the state of the spacecraft configuration so determined. From the raw or EU-converted spacecraft subsystem parameters the EOC can determine the health of the spacecraft subsystem by means such as limit checking (high/low, delta, rail), plotting parameters versus time, generating scatter plots for one parameter versus a correlated parameter, and compiling pertinent performance statistics. As part of housekeeping data monitoring, the EOC uses relevant information in the housekeeping telemetry and ground time reference to estimate the spacecraft time bias required for synchronization of the spacecraft clock to universal time coordinated (UTC). The estimated time bias can be uplinked as needed.

The EOC checks instrument housekeeping parameters to verify that each instrument stays within its resource allocation and has no adverse impact on the spacecraft or other instruments. Measurements of voltage and electric current at the instrument power supply, for example, enable the EOC to determine whether the instrument is operating within its power allocation. Temperatures taken at critical instrument telemetry points identify not only the thermal condition of the instrument, but also its impact on its environment. The health and safety of the instrument itself are the responsibility of the EOC.

Monitoring of the spacecraft and instrument housekeeping parameters can enable the detection of spacecraft subsystem failures and of instrument failures that affect spacecraft safety or subsystem support for other instruments. The FOT uses preplanned procedures to correct the faults and recover from the failures.

**Safemode Housekeeping Data.** Each EOS spacecraft can ensure its survival by switching to a safe mode of operation. This transition occurs under one of three conditions:

- The development of a deleterious set of conditions is not discernible or correctable by the SCC.
- A preset telemetry threshold is exceeded or an improper logic state is detected.
- Safe mode is invoked by ground command.

For example, in the case of the EOS-AM-1 spacecraft, the SCC’s control of the spacecraft is transferred to the attitude control electronics when the SCC itself has failed or when the SCC detects an attitude error that exceeds a preset value. In either case, the control of safemode handling passes back to an SCC only through ground commands.

During safe mode, the spacecraft C&DH subsystem assembles housekeeping data gathered from the spacecraft subsystems into a safemode housekeeping data packet for transmission to the ground either via the TDRSS SSA return-link (using the HGA, if available, or the Omni antenna) or an alternate space-to-ground link (e.g., DSN, WOTS, GN).

The safemode housekeeping data packets, on arriving at the EOC, undergo steps similar to those applicable to (normal mode) housekeeping data packets. The EOC extracts attitude sensor/ effector telemetry and related information from the safemode housekeeping data stream and provides them to the FDF. The EOC uses the safemode housekeeping parameters to monitor the safe operation of the spacecraft, which is essentially to determine whether spacecraft attitude maintenance and solar array pointing operations are being properly managed.

Concurrently with safemode spacecraft monitoring, the EOC analyzes previously accumulated spacecraft and instrument housekeeping data (and possibly SCC memory dump data) to determine the causes of anomalies. It also develops fault recovery procedures.

**Spacecraft Control Computer Memory Dump Data.** SCC memory dump data enable the EOC to track down the causes of anomalous spacecraft conditions. During normal operations, storage of the SCC load is verified by a CRC checksum technique (Section 3.4.4.6).

On request from the ground, the SCC dumps part or all of its memory contents to the ground via TDRSS S-band return-link service or the DSN. To protect against transmission errors, the ground may command it to downlink multiple copies of the memory dump.

As it does with instrument microprocessor memory (for the instruments under its control), the EOC maintains on the ground an image of the expected SCC memory. On receiving multiple copies of the SCC memory dump from EDOS, the EOC determines the best estimate of the memory contents and compares the estimate bit by bit with the SCC ground image. The FOT is notified of any discrepancies for subsequent action. If errors in the SCC software are suspected to be a cause of anomalous spacecraft subsystem behavior, the dump and ground image data are made available to the SDVF for in-depth analysis (Section 3.4.6.3). Anomalous spacecraft behavior may be traced to permanently damaged memory areas. Memory areas that are damaged are recorded as such in the data base to avoid their use in the future. (Section 3.4.7.1 describes the data base.)

#### 3.4.5.3 Overall Mission Monitoring

The EOC is responsible for the overall EOS flight mission monitoring, which focuses mainly on how well the EOS flight segment is executing the planned data gathering activities toward meeting the EOS mission objectives. The EOS mission objectives are established in the LTSP and LTIPs and are embodied in the scheduling process. EOC mission monitoring is, in effect, an effort to demonstrate the responsiveness of the detailed activity schedule to the LTSP and LTIPs.

Overall mission monitoring is based on three types of input:

- Spacecraft status maintained at the EOC
- History of support provided by external systems
- Instrument status reports from ISTs
- Instrument status maintained at the EOC

As part of overall mission monitoring, the EOC maintains a history of spacecraft subsystem operations. This history includes the results of spacecraft subsystem performance analysis (described in Section 3.4.6.3). Specifically, it includes information such as:

- Power subsystem performance, including power use by individual instruments and spacecraft subsystems
- Orbit and attitude maintenance history
- Spacecraft recorder management history
- Thermal Control subsystem performance
- Frequency of entry into safe mode and duration of operation in that mode

This information is useful in determining whether the spacecraft has been satisfying the needs of individual instruments.

The EOC also maintains records regarding the history of support provided by external systems such as:

- SN support
- DSN, GN, WOTS support (for contingency operations)
- EDOS service
- FDF support in providing accurate predicted orbit information
- FDF support for TONS operations and orbit maintenance operations

This information is useful in determining whether the ground support elements are adequately supporting the EOS mission.

Instrument status reports maintained at the EOC and received from individual ISTs provide information about whether the instruments are gathering science data as planned (e.g., per instrument or per set of instruments [multi-instrument coordinated observation]). The instrument status report includes information such as:

- Instrument health as determined from instrument housekeeping and engineering data monitoring
- Occurrences of anomalies and their respective characteristics (e.g., resolution status, duration)
- Frequency of entry into safe/survival mode, and duration in that mode
- Instrument science data quality assessment based on the quick-look processing activity or data available from the PI/TL

Using these data, the EOC determines the responsiveness of the actual performance of the flight segment to the LTSP and LTIPs. The project scientist reviews the conformance of the overall operation and the operation of a particular instrument to the science plans. The project scientist may modify the guidelines (e.g., for IP instrument TOOs or DAR priorities) to improve the satisfaction of the long-term plans. In addition, the EOC assesses the trends of the spacecraft subsystem performance to determine whether the spacecraft can continue to meet the mission requirements. The EOC provides the overall mission monitoring results to the project. The project scientist may have to update (with IWG approval) the LTSP and LTIPs to reflect any changes in spacecraft resources or capabilities. This may be done periodically, perhaps once a week.

## 3.4.6 Calibration and Analysis

### 3.4.6.1 Instrument Calibration

Instrument calibration is an ongoing operation. Before launch or during initial instrument testing, the instrument engineering and science teams at their SCF establish a calibration file containing the most up-to-date calibration results. A subset of this information associated with the engineering parameters or quick-look data display becomes part of the data base at the EOC. Calibration activities for the instrument continue after launch. For instruments that have sporadic calibrations, the instrument calibration activities must be scheduled with input from the instrument engineering team via the IST. Typically, data acquired from the calibration measurements are used by the instrument engineering team to update the calibration files contained at the EOC and DAAC. The updated information is sent to the EOC via the IST. For continuous in-flight calibration, calibration data are collected that typically can be used directly in the standard product processing at the DAAC and in EOC telemetry processing.

For some instruments, proper calibration requires additional, complementary measurements while the instrument is flying. The instrument scientists are responsible for the collection of these data (on the ground, in the air, or in space) and their corresponding processing. The instrument engineering or instrument science team would have to coordinate the request that data from the instrument be acquired coincident with the complementary data acquisition. The instrument team may need to make a subsequent request based on analysis of observed complementary data or problems occurring with the instrumentation for collecting the complementary data. In such a case, the new request would be treated as a late change when rescheduling the activity, if it required rapid turnaround.

### 3.4.6.2 Instrument Behavior Analysis

Behavior analysis is required for each EOS instrument to maintain an optimal and well understood level of performance. The instrument engineering team tracks changes in instrument behavior over time and watch for warnings and alarming trends in the instrument’s behavior. Anomalies uncovered as a result of instrument behavior analysis are reported to the EOC along with procedures for dealing with the anomalies.

Instrument behavior analysis is closely related to instrument monitoring (Section 3.4.5.1), although they differ in significant ways. Instrument behavior analysis demands special expertise with a detailed knowledge of instrument construction, detector capabilities, and the data produced. The analysis (which is typically performed periodically) focuses on long-term effects or the cause of short-term anomalies. In contrast, instrument monitoring requires 24-hour-a-day operations, but needs much less expertise.

Although the overall health and performance of an instrument are the responsibility of the instrument engineering team, that team may delegate certain levels of maintenance to the EOC. Thus, the routine, round-the-clock monitoring of instrument health, the first line of defense for ensuring the scientific productivity of the instrument, typically occurs at the EOC. Such monitoring involves tracking engineering data and command status, and routine analysis of quick-look science data. Reactions follow step-by-step procedures provided by the instrument engineering team.

The instrument engineering team typically performs the more detailed instrument behavior analysis, which involves complex manipulation of scientific and calibration data and includes long-term trend analysis of these results and of many engineering parameters. Detailed instrument behavior analysis typically occurs at the instrument team’s SCF, supported by processing at the DAAC. Analysis results may prompt the instrument engineering team to provide the EOC with new or updated routine monitoring procedures.

As part of instrument behavior analysis, the instrument engineering team may use the IST to view quick-look data (which may be an orbit’s worth of data per day for some mapping-type instruments). This team’s involvement in this analysis may be most common at the earliest phases of the mission when it is not clear what information provides the fullest understanding of the instrument’s behavioral characteristics. Processing and examination of these data may become more automated as the mission progresses. As a result, this function could migrate from the instrument engineering team to FOT members or the instrument operations team.

### 3.4.6.3 Spacecraft Behavior Analysis

The EOC FOT provides the analysis required for operations and sustaining engineering of the U.S. spacecraft. This analysis includes trend analysis, configuration monitoring, spacecraft resource management, and fault management. The analysis can be performed in real time or offline, using replay or operations history data. The analysis results are used as input to overall mission monitoring (Section 3.4.5.3).

Automation tools, such as expert systems, perform some of the analyses and provide notices or recommendations to the FOT. The automation tools are capable of providing explanations of their conclusions. Such explanations describe the flow of logic that led to the conclusion(s). The operators are responsible for initiating any action on the notices or recommendations. The FOT may coordinate with other elements when special expertise is needed. For example, the FDF is consulted for orbit adjustments. The spacecraft simulator assists in solving flight software problems.

Spacecraft resource management analysis evaluates the ability of the spacecraft subsystems to provide the resources needed to operate the instruments and spacecraft. It may monitor, for example, a decrease in spacecraft recorder storage capacity or the degradation of EPS components over time. The analysis results are used to influence long-term plans and to modify operational procedures.

The EOC, as well as the spacecraft simulator, has tools to aid in the development, test, and update of operations procedures. These procedures provide a mechanism to automate routine operations functions.

Spacecraft fault management is a major EOC responsibility. If an onboard fault occurs, the FOT's first action is to stabilize the situation. For instance, safeing the instrument or spacecraft if necessary. After the spacecraft and instruments are in a safe and stable state, the FOT uses its analysis tools and the expertise at the respective ISTs to understand the fault and to develop or coordinate a recovery or work around procedure. If it isolates the faults to within an instrument, the responsibility for fault recovery moves to the PI/TL. The EOC FOT is also responsible for coordinating the resolution of communications faults that affect EOS flight operations.

## 3.4.7 Data Management

Data management addresses operations databases and operations history data, as well as managing documentation, both on line and off line, to support operations and maintenance.

### 3.4.7.1 Operations Databases

Two types of data bases support EOS flight operations: a spacecraft data base and a number of instrument data bases. The EOC maintains and uses a data base for each spacecraft. The data base contains information such as telemetry formats, calibration curves, command verification procedures, display formats, and automated operations procedures. Instrument information needed for spacecraft operation is also part of the spacecraft data base. The FOT maintains the information in the spacecraft data base, changing information as a result of such changes as analysis, upgrades, interface changes, and the development of new procedures. The spacecraft data base is under configuration control; changes are made in accordance with documented change control procedures.

The EOC also maintains instrument data bases (one logical data base per instrument). The instrument data base contains the same type of information for the instruments as the data base for the spacecraft. The instrument design and/or engineering team provide the instrument-specific contents. The instrument data base may be managed by the FOT or by the instrument engineering team via the IST.

Tools support the definition and management of these data bases. They assist the operators in generating input, modifying the existing contents, checking the data base for syntax and consistency, and producing reports on the contents.

#### 3.4.7.2 Operations History Data

Operations history data consist of a log of operations activities and information. These data include plans, schedules, commands, housekeeping data, engineering data, and relevant operator actions. The EOC sends operations history data to the GSFC DAAC for archival when it no longer expects to need them, typically after 7 days. Subsets of the history data can be retained for longer periods of time, if necessary.

History data (e.g., fault information, maintenance status) are made available to the SMC. The PI/TL and instrument engineering team also have access to these data via the IST.

### 3.4.8 Flight Operations Support

Flight operations require several support activities to function effectively and reliably. The personnel associated with the various FOT tasks need appropriate training, management, and maintenance and logistical support.

#### 3.4.8.1 Flight Operations Training

Flight operations personnel receive several types of training from different sources. The flight operations training process begins prior to launch and continues throughout the mission to support upgrades, personnel changes, workarounds, and future launches.

flight operations training consists of formal classroom sessions, on-the-job training, and simulations. Classroom training emphasize the knowledge of space and ground segments. On-the-job training and simulations emphasize the execution of operational procedures required to operate the associated flight operations systems.

The spacecraft manufacturers and the instrument science teams provide operations training. This training provides structured materials and courses that describe all normal and contingency operations including spacecraft and instrument architecture, science data acquisition method, deployment and safeing operations, calibration operations.

IWG representatives and/or the project scientist provide training on the evaluation of IP instrument TOOs according to IWG guidelines. The project scientist provides clear procedures for contacting the IWG or project scientist in the event of a conflict or other unresolvable problem that negatively affects the science aspect of the mission.

The flight operations developers train the operations personnel in operating the flight operations equipment and exchanging data and directive information with the computing systems. This training includes input and output techniques, menu selections, procedures, planning and scheduling capabilities, command generation and submission, monitoring capabilities, and help facilities. IST users are trained by the IST developer.

Communications personnel provide training on SMC processes and procedures for the ground systems. This training includes security, maintenance, logistics support, and testing. The ECS project provides training on project policies, procedures, and methodologies. This training includes report generation, contingency operations, and fault recovery.

The flight operations tasks require that operations personnel demonstrate the knowledge and ability to perform appropriate operational functions. All flight operations personnel enter into a formal program of certification. This program ensures that those assigned to console positions are knowledgeable and competent. Cross-training will be an integral part of the flight operations training. Cross-training will be provided to cover absences, as well as for advancement, and job enrichment.

#### 3.4.8.2 Resource Management

The EOC element must be managed to ensure proper scheduling, configuration, operations, monitoring, repair, and testing. These element management functions may be performed as part of the management of the larger facilities of which the elements are part. Support personnel (i.e. the Operations Coordinator, Operations Controller, and Ground Controller) manage their elements in support of the FOT or instrument operations team. They schedule, configure, monitor, repair, and test the EOC hardware components and manage EOC security.

The configuration of the hardware does not change often. Scheduling is required for routine maintenance, tests, and special operations (e.g., launch) and is semi-automatic. The scheduling of tests involving other EOSDIS elements is coordinated with the SMC.

The operations support personnel configure the hardware components. They implement any scheduled changes and reconfigure the components (e.g., workstations) in the event of an anomaly. The operations support personnel perform any software initialization required as part of the reconfiguration.

Both the operations support personnel and the FOT can monitor the EOC. Information on hardware status, software configuration, system performance, and interface activity is available for display.

Automated systems, such as expert systems, may support the monitoring and reconfiguration of the element. When operations support personnel identify a hardware failure or problem, they reconfigure the element to work around the problem. (The EOC has no single points of failure for real-time operations functions.) In the event of a hardware failure, operations support personnel can designate a spare component or one that is supporting a lower priority function to provide the failed function. They schedule the failed component for maintenance. Systems undergo testing before they are returned to operations.

The FOT or operations support personnel can also perform tests on operational equipment and interfaces to ensure proper operation or help isolate problems. These checks do not interfere with ongoing operations.

Operations support personnel are responsible for managing the security of the element. They maintain passwords and access authorizations for all element users. The SMC coordinates security activities.

#### 3.4.8.3 Maintenance and Logistics

Maintenance services as provided to the EOC around the clock. Routine maintenance is performed in accordance with OEM specifications. A logistics facility for critical spares and consumables is located in the vicinity of these elements.

In contrast, IST hardware maintenance is not a NASA responsibility. The PI or TL provides the hardware on which the IST is hosted, and has the responsibility for maintaining this hardware.

#### 3.4.8.4 Integration and Test

The flight operations elements participate in integration and test activities throughout the EOS mission. They support testing (for periodic hardware and software upgrades), anomaly investigations, and replacement launches for EOS spacecraft. After the launch of the first EOS spacecraft, all integration and test activities are also conducted simultaneously with normal operations.

Initially, the flight operations elements participate in testing at the individual element level. During the development period, the EOC develops standard data sets for exercising scheduling, commanding, and monitoring functions. These standard data sets are developed internally as part of element testing and maintained throughout the mission. When external data from simulators or from the actual spacecraft and instrument hardware become available, they are used to develop standard data sets as well.

The EOC maintains standard data sets to test all spacecraft telemetry formats including spacecraft housekeeping, SCC dump, and safemode formats. The spacecraft contractor and EOC cooperate to test and validate the SCC software and the EOC command functions.

The EOC also maintains data sets to test all command and telemetry functions for the EOS instruments. The instrument telemetry formats include spacecraft housekeeping, instrument engineering, and instrument science (for quick-look science processing).

In general, IST testing is a subset of EOC testing because these flight operations elements share many functions. ISTs are also tested for compliance with the toolkit standards and for their interfaces with the EOC (as appropriate).

The EOC conducts separate interface tests with other EOSDIS components, such as the DAAC, over the ESN. The interface testing between the EOC and the spacecraft simulator is conducted over Ecom lines.

Flight operations supports a number of tests before launch. Some EOC functions required for instrument operations may be tested with the instruments before they are delivered to the spacecraft contractor for integration. These tests depend on several factors, which include the instrument and associated EOC functions development schedule and the capabilities of other test equipment.

The EOC is also involved in spacecraft integration tests. These integration tests are the most extensive tests of the pre-launch phase exercising as many operations functions as feasible.

The flight operations elements participate in a number of end-to-end tests before the launch of each spacecraft. These tests include other NASA institutional elements including NCC, TDRSS, and the FDF, as well as other EOSDIS elements such as the EDOS, the spacecraft simulator, the SDVF, the DAAC, and SMC. Flight operations also supports end-to-end tests at the spacecraft integration site and the launch site (normally at Vandenberg).

The flight operations elements also support both interface testing and end-to-end testing with IP elements. The EOC conducts interface tests with the instruments on U.S. spacecraft.

## 3.4.9 Orbit Operations

### 3.4.9.1 Launch and Early-Orbit Operations

Launch and early-orbit operations involve several spacecraft operations phases (Figure 3.4.9.1-1). The procedures to place the spacecraft into orbit must be performed correctly the first time: There is very little time to correct errors. The ECS FOT supports the spacecraft manufacturers launch and early-orbit activities. The first operations encountered by the FOT are some of the most critical of the spacecraft’s life cycle. To ensure proper spacecraft activation, checkout, and verification, the ECS FOT in conjunction with spacecraft manufacturer uses preplanned and prevalidated flight operations plans and procedures developed in coordination with operations and engineering teams for both nominal and possible contingency scenarios. Multiple simulations and dry runs prepare the FOT and support staff as much as possible for nominal and contingency activities.

### 3.4.9.2 Pre-launch Phase

The launch operations team configures the spacecraft into launch mode with EOC support. This phase normally begins approximately 60 days prior to launch when the spacecraft arrives at the launch site (Vandenberg Air Force Base for most EOS spacecraft). The spacecraft is then mated to the launch vehicle, and both undergo a variety of inspections and tests. Initially, this is done in the processing facilities. It is subsequently done on the launch pad to establish launch readiness of the launch vehicle, the spacecraft, and the associated ground elements.

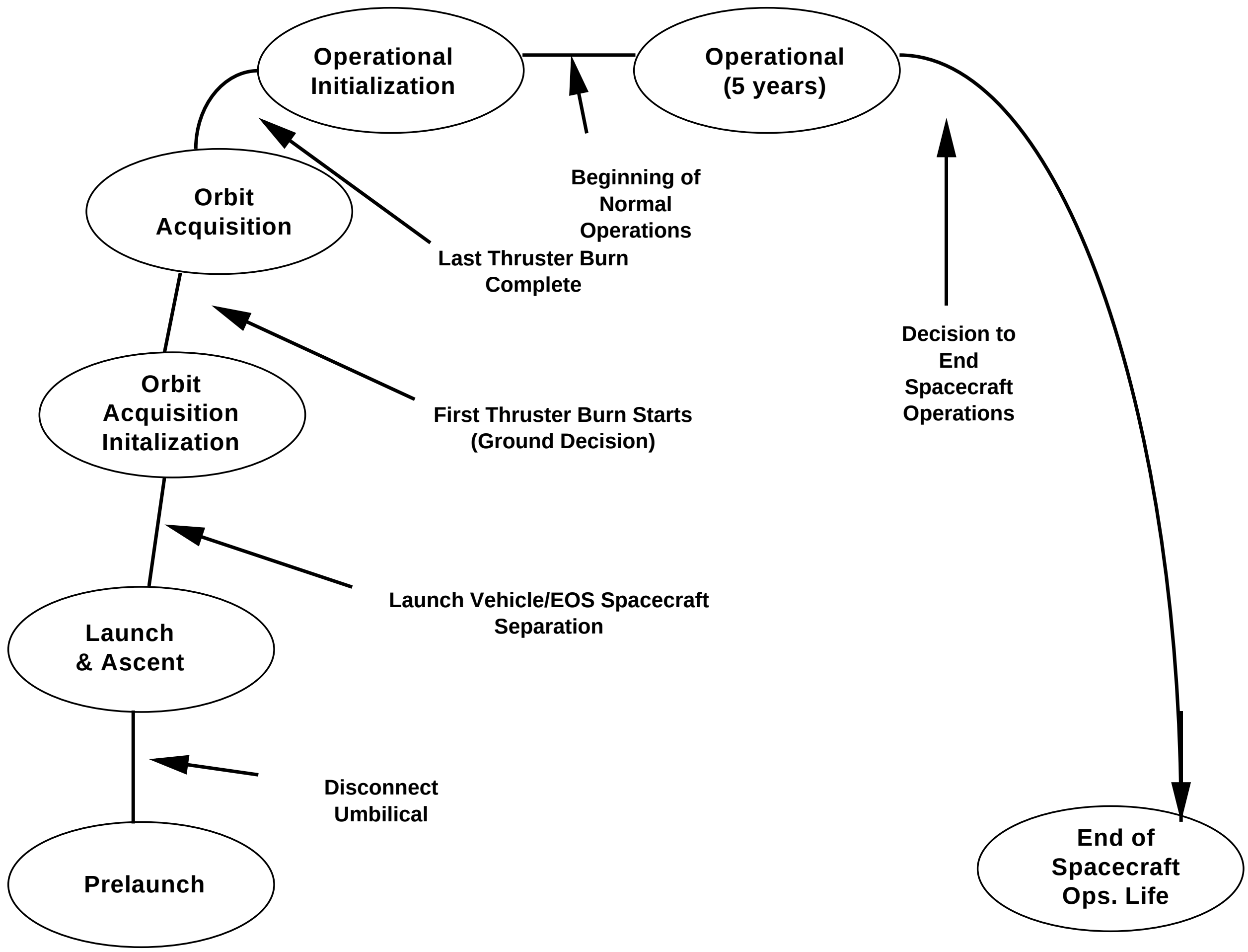



***Figure 3.4.9.1-1. EOS Spacecraft Operations Phases***

The EOC supports the launch operations team by monitoring, verifying, and coordinating various activities needed for launch preparation. In particular, the EOC:

- Coordinates with the NCC to obtain the needed TDRSS contacts
- Verifies that the several ground systems and networks are ready for command and telemetry operations in both nominal and emergency conditions
- Updates and adjusts the launch and early-orbit plans and procedures
- Monitors the health and safety of the spacecraft and instruments after the spacecraft has been moved to the launch pad, while it is being mated to the launch vehicle, and while it is awaiting launch on the launch pad.

The EOC also supports launch configuration validation and verifies that the spacecraft parameters are within specified limits.

#### 3.4.9.3 Launch and Ascent Phase

Primary operations responsibility is transferred from the launch site operations facility to the EOC when the launch pad umbilical is disconnected. During launch/ascent, the EOC monitors the spacecraft housekeeping data and any launch vehicle data needed to verify the health and safety of the spacecraft and instruments. A special operations area at the launch site operations facility augments the EOC by providing additional space and supporting systems for the larger operations team required at launch.

#### 3.4.9.4 Orbit Acquisition Initialization Phase

During spacecraft separation from the launch vehicle and injection into orbit, the EOC monitors the spacecraft housekeeping data to verify spacecraft and instrument health and safety, and it checks the command and dump links. The EOC verifies the execution of stored command, establishment of S-band communications with TDRSS via the omni-directional antennas, acquisition of the Earth, and deployment of the solar array.

#### 3.4.9.5 Orbit Acquisition Phase

During the days (up to 7) of orbit acquisition, the EOC establishes full command and control of the spacecraft. The EOC monitors the spacecraft housekeeping data to verify spacecraft and instrument health and safety, deployment of the HGA, TDRSS S-band acquisition by HGA, and the status of spacecraft resources. In coordination with the FDF, the EOC determines the required orbit, plans trim burns for inserting the spacecraft into its nominal orbit, and checks out the TONS.

#### 3.4.9.6 Operational Initialization Phase

Once the spacecraft is on orbit, the EOC takes 3 to 5 days to perform a complete spacecraft subsystem checkout while the instruments are still in a safe, non operating state. The EOC uses preplanned procedures to handle non-nominal operation of critical subsystems to produce nominal operations or approved alternatives. After nominal operation of critical subsystems is verified, preplanned procedures turn on all primary subsystems to verify their nominal operation. Preplanned activities may include loading new stored command/data tables and verifying command load storage, stored command execution, and subsystem status.

When spacecraft subsystem operations have been checked out, the instrument turn on and checkout begins. The instruments are turned on one at a time in a sequence that takes into account instrument-specific amounts of time for outgassing or thermal equilibrium. Instrument checkout is performed in real time by the EOC with a command link available to adjust the checkout procedure in the event of an unexpected problem. Post launch checkout is the only phase of on-orbit operations where real-time instrument commanding is scheduled well in advance. The instrument engineering team augments the FOT during this period; the two teams work at the EOC.

Checkout of the spacecraft and instruments concludes with calibration of spacecraft subsystems and instruments to detect pointing errors and to establish scientific correlations. The EOC/IST evaluates misalignments or other calibration problems to produce corrective data tables, from which SCC/instrument table loads are generated, validated, and uplinked.

When the instruments and all primary subsystems have been checked out, the EOC configures the spacecraft into the operational mode. Nominally, this occurs 60 days after the start of the operational initialization phase.

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# Abbreviations and Acronyms

| | |
|---|---|
| ADC | Affiliated Data Center |
| AIRS | Atmospheric Infrared Sounder |
| AM | Morning (ante meridiem) – see EOS AM;  archive manager |
| API | Application Programming Interface |
| APID | Applications Process Identifier |
| ASF | Alaska SAR Facility |
| ASTER | Advanced Spaceborne Thermal Emission and Reflection Radiometer |
| BAP | Baseline Activity Profile |
| C&DH | Command And Data Handling |
| CAC | Command Activity Controller |
| CCB | Configuration Change Board |
| CCD | Charge-Coupled Drive |
| CCR | Configuration Change Request |
| CCSDS | Consultative Committee for Space Data Systems |
| CERES | Clouds and Earth's Radiant Energy System |
| CERT | Computer Emergency Response Team |
| CMS | Command Management System |
| COLOR | Ocean Color - see EOS COLOR |
| COTS | Commercial Off-The-Shelf |
| CRC | Cyclic Redundancy Check |
| CSMS | Communications and System Management Segment |
| DAAC | Distributed Active Archive Center |
| DADS | Data Archive and Distribution System ( obsolete ECS element name) |
| DAR | Data Acquisition Request |
| DAS | Direct Access System |
| DB | Direct Broadcast |
| DID | Data Item Description |
| DIM | Distributed Information Manager |

| | |
|---|---|
| DIT | Data Ingest Technician |
| DS | Data Specialist |
| DSN | Deep Space Network |
| ECOM | EOS Communications |
| ECS | EOSDIS Core System |
| EDOS | EOS Data and Operations System |
| EOC | EOS Operations Center |
| EOS | Earth Observing System |
| EOSDIS | EOS Data and Information System |
| EPS | Electrical Power Subsystem |
| ESA | European Space Agency |
| ESDIS | Earth Science Data and Information System |
| ESN | EOSDIS Science Network |
| ESSIT | ECS Science Software Integration Team |
| EU | Engineering Unit |
| FDF | Flight Dynamics Facility |
| FOS | Flight Operations Segment (ECS) |
| FOT | Flight Operations Team |
| FSE | Flight Segment Engineer |
| GCDIS | Global Change Data and Information System |
| GCRP | Global Change Research Project |
| GN | Ground Network |
| GUI | Graphical User Interface |
| HCI | Human-Computer Interface |
| HDF | Hierarchical Data Format |
| HTML | HyperText Markup Language |
| HTTP | Hypertext Transport Protocol |
| I&T | Integration And Test |
| ICC | Instrument Control Center |
| IMS | Information Management System (obsolete ECS element name) |
| IP | International Partners |

| | |
|---|---|
| IP-ICC | International Partners Instrument Control Center |
| IST | Instrument Support Toolkit |
| IWG | Investigator Working Group |
| JPL | Jet Propulsion Laboratory |
| KSA | Ku-band single access |
| LAN | local area network |
| LaRC | Langley Research Center |
| LIM | Local Information Manager |
| LIS | Lightning Imaging Sensor |
| LSM | Local System Manager |
| LTIP | Long Term Instrument Plan |
| LTSP | Long Term Science Plan |
| M&O | Maintenance And Operations |
| MISR | Multi-Angle Imaging SpectroRadiometer |
| MODIS | Moderate Resolution Imaging Spectrometer |
| MOPITT | Measurements of Pollution in the Troposphere |
| MSFC | Marshall Space Flight Center |
| MSS | Systems Management Subsystem (CSMS) |
| MTPE | Mission to Planet Earth |
| MUI | Management User Interface |
| Nascom | NASA Communications Network |
| NASDA | National Space Development Agency |
| NCC | Network Control Center |
| NMF | Network Management Facility |
| NOAA | National Oceanic and Atmospheric Administration |
| NSI | NASA Science Internet |
| OCR | optical character reader |
| PDB | project data base |
| PDR | Preliminary Design Review |
| PGE | Product Generation Executable |
| PGS | Product Generation Subsystem (obsolete ECS element name) |

| | |
|---|---|
| PI | Principal Investigator |
| PI/TL | Principal Investigator/Team Leader |
| PIP | "P" Internet Protocol |
| PSAT | Predicted Site Acquisition Table |
| PSCN | Program Support Communications Network |
| Q/L | Quick Look |
| QA | Quality Assurance |
| RID | Review Item Discrepancy; Request for Information Disposition |
| ROM | read only memory |
| SCC | spacecraft control computer |
| SCF | Science Computing Facility |
| SDB | Spacecraft Data Base |
| SDP | Science Data Processing |
| SDPF | Sensor Data Processing Facility (GSFC) |
| SDPS | Science Data Processing Segment |
| SDR | Software Design Review; System Design Review |
| SDVF | Software Development and Validation Facility |
| SMC | Service Management Center |
| SN | Space Network |
| SPSO | Science Processing Support Office |
| SRR | System Requirements Review (ECS) |
| SSM/I | Special Sensor Microwave/Image |
| SWIR | Short-Wave Infrared |
| TDRSS | Tracking and Data Relay Satellite System |
| TIR | Thermal Infrared |
| TL | Team Leader |
| TONS | TDRSS Onboard Navigation System |
| TOO | Target Of Opportunity |
| TRMM | Tropical Rainfall Measuring Mission (joint US-Japan) |
| TSDIS | TRMM Science Data and Information System |
| UAV | User Antenna View |

| | |
|---|---|
| UTC | Universal Time Coordinated |
| VNIR | Visible and Near Infrared |
| WAN | Wide Area Network |
| WOTS | Wallops Orbital Tracking Station |